instruction manual

EP ENG ~~5-21~~ R4 G

INSTRUCTION MANUAL

Serial # 400

MODELS 7160 & 7150

EPUT® METER

INSTRUMENT SERVICES

Beckman®

Berkeley Division

EP ENG ~~5-21~~ R4G

INSTRUCTION MANUAL

Serial # 400

MODELS 7160 & 7150
EPUT® METER

Lot 20 and above
SER. 1080

NOTE

IF MODEL NUMBER IS FOLLOWED BY AN INKED-IN LETTER, THE INSTRUMENT THIS MANUAL ACCOMPANIES HAS BEEN MODIFIED. IF SO, SEE SECTION SIX ON MODIFICATIONS BEFORE READING FURTHER.

BERKELEY division
Beckman Instruments, Inc.

20 February 1956

WARRANTY

Instruments sold by Berkeley Division, Beckman Instruments, Inc., (hereafter called "the Company") are warranted only as stated below.

Subject to the exceptions and upon the conditions specified below, the Company agrees to correct, either by repair, or, at its election, by replacement, any defect of material or workmanship which develops within one year after delivery of the instrument to the original purchaser by the Company or by an authorized representative, provided that investigation and factory inspection by the Company discloses that such defect developed under normal and proper use.

The exceptions and conditions mentioned above are the following:

(a) All instruments claimed defective must be returned to the Company, transportation charges prepaid, and will be returned to the customer with the transportation charges collect.

(b) The Company makes no warranty concerning components or accessories not manufactured by it, such as tubes, fuses, batteries, etc. However, in the event of the failure of any component or accessory not manufactured by the Company, the Company will give reasonable assistance to the purchaser in obtaining from the respective manufacturer whatever adjustment is reasonable in the light of the manufacturer's own warranty.

(c) The Company shall be released from all obligations under its warranty in the event repairs or modifications are made by persons other than its own service personnel or authorized representatives' personnel unless such repairs by others are made with the written consent of the Company.

(d) Except as stated above, the Company makes no warranty, express or implied (either in fact or by operation of law), statutory or otherwise; and, except to the extent stated above, the Company shall have no liability under any warranty, express or implied (either in fact or by operation of law), statutory or otherwise.

(e) The Company expressly disclaims any liability to its customers, dealers, and to users of its products, and to any other person or persons for consequential damages of any kind and from any cause whatsoever arising out of or in any way connected with the manufacture, sale, repair, replacement of, or arising out of or in any way connected with the use of any of its products.

(f) Representations and warranties made by any person, including representatives of the Company, which are inconsistent or in conflict with the terms of this warranty (including but not limited to the limitation of the liability of the Company as set forth above) shall not be binding upon the Company unless reduced to writing and approved by an officer of the Company.

(g) This warranty shall be governed by the laws of the State of California.

Claims for damage in shipment should be filed promptly with the transportation company.

All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate. Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, Berkeley division of Beckman Instruments, Inc., Richmond 4, California.

REPAIR SERVICE

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing. Repair work will be performed only upon receipt of a written purchase order or authorization. Instruments to be repaired should be addressed to SERVICE AND REPAIR DEPARTMENT with transportation charges prepaid. Repaired instruments will be returned to the purchaser with transportation charges collect.

Berkeley reserves the right to make changes in design at any time without incurring any obligation to modify equipment previously purchased to conform to subsequent design changes.

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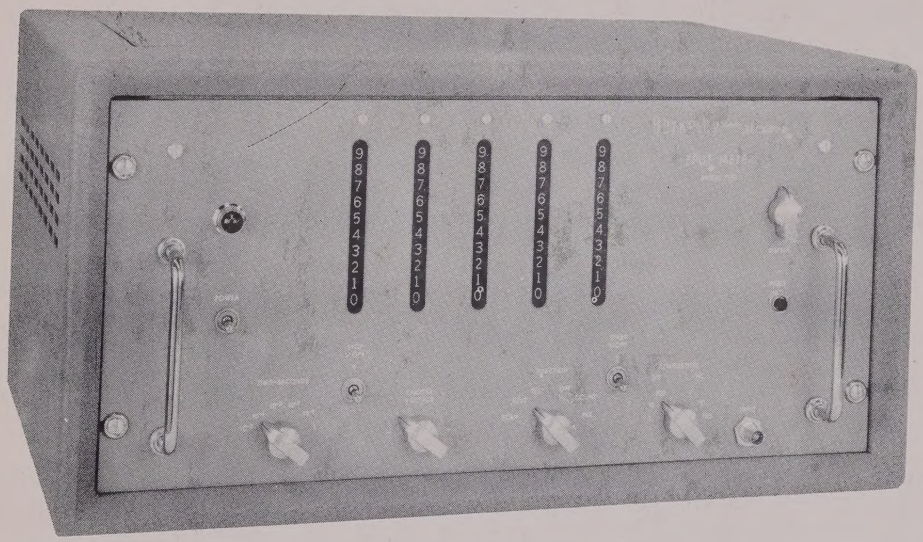
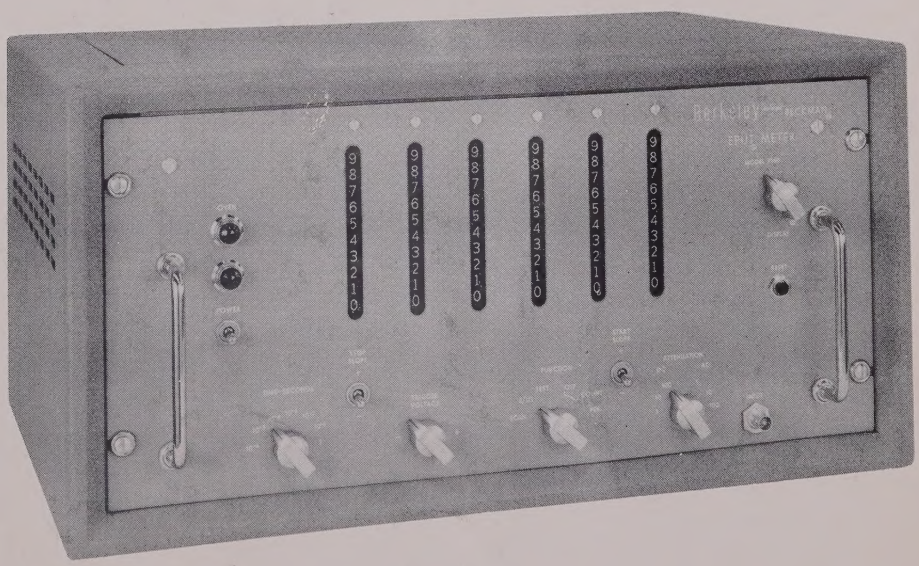


Model 7150



Model 7160

I Introduction

DESCRIPTION

The EPUT* Meter, Models 7160 and 7150, is a electronic counter designed primarily to count events at high speed during a precise time interval. The events may be any optical, physical or electrical occurrences which can be translated into voltage changes. Voltage changes applied to the input of the instrument trigger sharp voltage pulses on an input channel. These pulses are counted by cascaded decimal counting units (DCU's) during a precise interval established by a clock-pulse generator. The count appears in decimal form on lighted lucite panels. When the input voltage changes are successive cycles of a regular signal, the result is a frequency measurement.

Since the clock signal is extremely precise, the count displayed is essentially accurate to ± 1 event. This is the irreducible error of electronic counters. At low frequencies (for example, 50 cps) an error of one count is appreciable. Therefore, the counter is equipped to measure the period of such a signal with great accuracy and the frequency may then be calculated. When making period measurements, clock pulses are counted during the interval between successive cycles of the input signal.

The Model 7160 differs from the Model 7150 primarily in the highest frequency which may be measured and in the smallest unit of time measurement available. The Model 7160 will measure frequencies as high as 1MC, whereas the Model 7150 is limited to 100KC. The Model 7160 will make time measurements in one-μsecond units while the smallest unit of time measurement on the Model 7150 is 10 μseconds.

SPECIFICATIONS

FUNCTIONS

1. Measures frequency or counts events-per-unit-time over a maximum automatic time interval of 1 second with a manual extension beyond 1 second for extreme accuracy.
2. Measures period of a wave or the width of a pulse.
5. Counts events over a manually controlled time interval.
6. Makes self-check on accuracy of clock signals and Decimal Counting Units.
7. Performs any of the above functions with an external frequency substituted for the internal oscillator frequency.

* Trademark Registered U. S. Patent Office.

PERFORMANCE CHARACTERISTICS

Input Trigger Channel

Input frequency range
d-c to 1MC

Input impedance
10 megohms in parallel with 40 $\mu\mu$f

Input sensitivity
100 millivolts rms, 0.3 volts peak-to peak from d-c to 1MC

Input voltage attenuation
1, 10 or 100 a-c and d-c

Overload limits
Input impedance drops below 10 megohms when input voltage rises above +1 volts d-c after attenuation.

Trigger voltage level
Adjustable from -1 to +1 volts at the attenuated signal

Trigger slope
Plus or minus

Clock-pulse Generator

Output frequency
Selectable in decade steps from 1 cps to 1MC on the Model 7160 and from 1 cps to 100KC on the Model 7150

Output signal
0.25 μseconds pulse 5 volts high out of 5000ohms, available for external use.

Oscillator Stability
Model 7160: 3 parts in 10^7 per week
Model 7150: 1 part in 10^5 per day

Gate, Control Circuits and DCU's

Resolution
Model 7160 0.8 μseconds
Model 7150 5 μseconds

Capacity
Model 7160 10^6 counts
Model 7150 10^5 counts

Display
Continuously variable from .05 to 5 seconds.

4-line code from DCU's to external connector

APPLICATIONS

The Berkeley EPUT Meter can be used to make a wide variety of frequency and time measurements both in the laboratory and on the production line. It is useful in designing transmitters, receivers, tuned circuits, crystals, oscillators and other equipment which must have definite frequency characteristics. On the production line the instrument is ideal for making stability checks on transmitting and receiving equipment and on crystals during heat cycling. It may also be used to calibrate less accurate frequency monitoring equipment.

Various transducers such as photocells, magnetic pickups and switches may be used to produce voltage changes representing physical events. So equipped, the instrument will measure the characteristics of such events relative to time. Some of the known applications of the instrument are:

Frequency measurements
Relay and switch timing
Viscosity and ballistic measurements
Elasticity measurements
Tachometry
Telemetery
Pulse height analysis
Oscilloscope time base calibration
Use as a secondary frequency standard

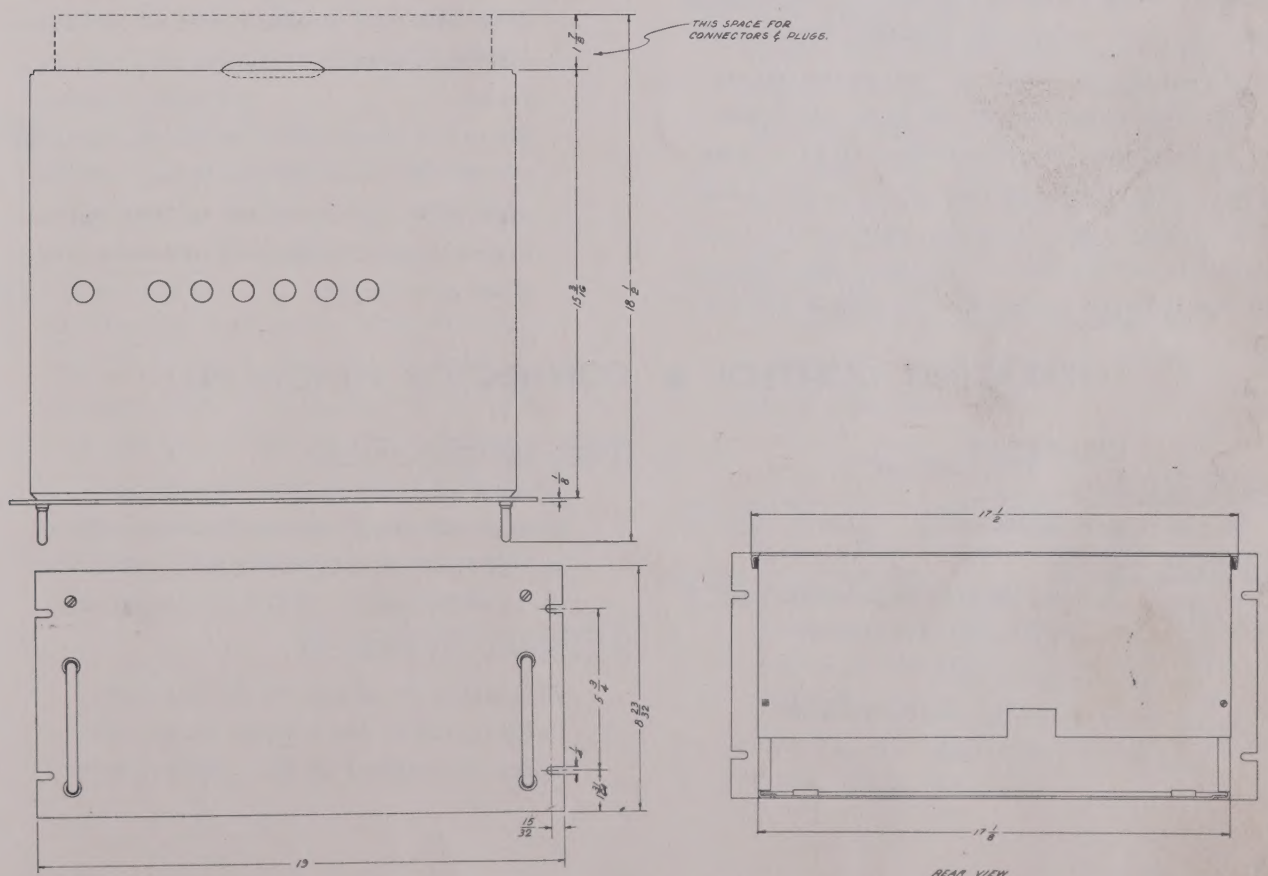
The versatility of the instrument can be fully utilized only when it is equipped with the proper accessories. Numerous transducers such as the Model 442 Reflecting Tachometer as well as sev-

eral data recording and data reduction instruments are available at Berkeley. The Model 1452 Digital Recorder, designed for use with this instrument, converts count information into a printed record. The unit prints the count accumulated by the counter during each counting period. The printed count appears sequentially in Arabic numerals on a standard adding machine tape. This recorder is ideal for making long term stability checks, recording transients, monitoring, or for making a permanent printed record in control or measuring systems.

The Model 1440 Series, Data Reduction Converters, convert digital information from the counter to a form suitable for actuating an IBM summary punch or an electric typewriter. These converters have uses similar to those of the Digital Recorder. The Model 1440S is designed for use with the IBM Summary Punch Type 523; the Model 1441S, for use with the IBM Summary Punch Type 615, and the Model 1442S, for use with an electric typeweiter. On special order Berkeley will prepare a modification of the Model 1442S which will drive a teletype or a microwave link. In this way count information may be made instantaneously available at various remote locations.

The Model 1445 Digital to Analog Converter converts the count accumulated during each counting period to a representative voltage level. This voltage is held until a new count is completed when it changes to conform with the new count. The unit may be used with a self-balancing potentiometer to provide an analog record, or the changing voltage level may be used to control the operation being monitored.

With the exception of the modified Model 1442S, the instruments described above are standard accessories. Other converters, transducers and special equipment may be ordered to meet specific problems.



CHASSIS MOUNTING DIMENSIONS, MODELS 7150, 7160, 7250, 7260, 7350, 7360

2 Operation

OVER-ALL DESIGN

The counter will make two types of measurements aside from simple counting.

1. It will count the number of events occuring during a precise time interval. This is known as Events-Per-Unit Time or E/UT Operation. Frequency measurements are made in this way. The SCAN function is a variation of this operation.
2. It will measure the time interval between two events represented on the same input channel. This is known as PERIOD Operation.

If the events mentioned above are not initially voltage changes, appropriate transducers are used to produce voltage changes representing the events at the counter INPUTS. An input trigger channel within the counter converts the voltage changes it receives into sharp pulses. A clock-pulse generator in the instrument produces similar pulses separated by a precise time interval. Besides these two pulse sources the counter contains an electronic gate and a chain of decimal counting units (DCU's). The DCU's count and indicate the number of pulses which pass through the gate between a start pulse which opens it and a stop pulse which closes it.

The FUNCTION switch determines the type of measurement made by selecting the pulse source which provides each of the three signals -- pulses to be counted, the start pulse and the stop pulse.

1. Under E/UT Operation the input channel provides pulses which are counted over the known time interval between start and stop pulses from clock-pulse generator. With the proper placement of a decimal point the lighted DCU's indicate events or cycles per second.
2. Under PERIOD Operation pulses of known frequency from the clock-pulse generator are counted over an unknown interval between start and stop pulses from the input channel. Since the clock-pulse frequency is equal to the 1MC or 100KC oscillator frequency divided by a power of 10, the time measurement appears directly in decimal fractions of a second.

OPERATING CONTROL & CONNECTOR FUNCTIONS

CONTROLS

POWER switch

Turns power on and off.

FUNCTION switch

1. Interconnects major components to perform the measurement indicated by the pointer.
2. Used to manually control COUNT and SCAN operations.

TIME-SECONDS switch

Selects time interval for events-per-unit-time & TEST measurements and unit of time measurement for PERIOD measurements.

ATTENUATION controls

Attenuates the signal at the adjacent INPUT jack by the voltage factor to which the pointer is set. When turned

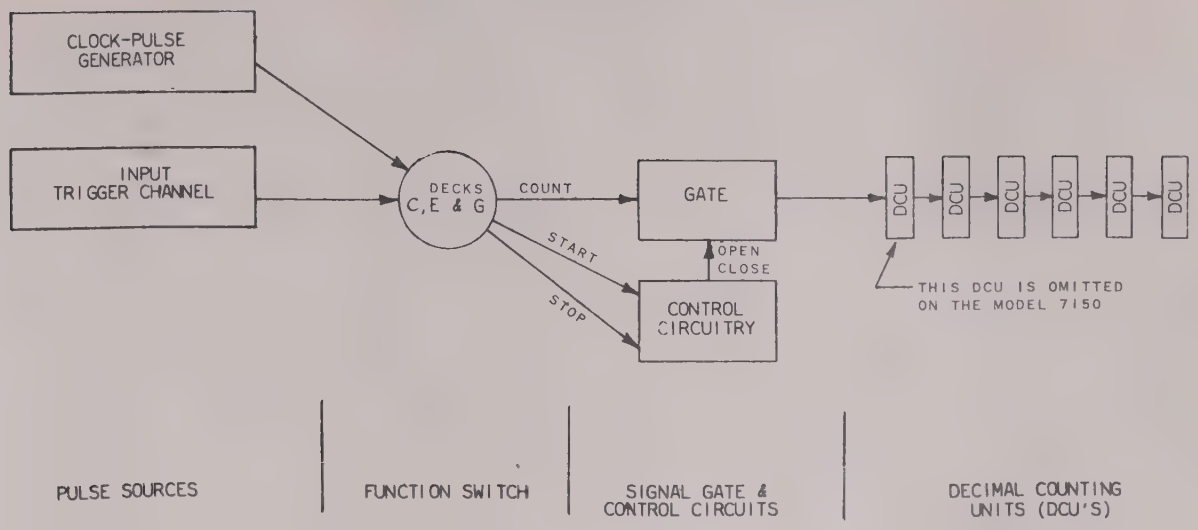


Figure 2 Signal Paths between Major Components

to the AC side only the a-c component of the input signal reaches the input trigger channel.

TRIGGER VOLTAGE Controls

Selects the instantaneous voltage at which the attenuated signal triggers the adjacent input channel.

SLOPE switches

Selects the slope of the input voltage waveform which triggers the input channel pulse used to operate the gate and control circuitry.

See "PERFORMING SPECIFIC OPERATIONS" to determine the function of the SLOPE switches at a particular position of the FUNCTION switch.

DISPLAY Time Control

Determines how long the instrument holds a reading before resetting and beginning another count. When this control is turned to the extreme clockwise position, the instrument will hold a reading until the manual RESET button is depressed.

Manual RESET button

Removes the previous reading and readies the instrument to begin another counting period.

CONNECTORS

INPUT Trigger Channel jack

Input to the Trigger Channel.

FREQuency Jack (Chassis Rear)

When the EXT-INT switch is at INTernal the oscillator signal is available here. When the switch is at EXTernal, the external reference frequency must be connected to this jack.

COUNTER INPUT ADJUSTMENTS

INPUT ADJUSTMENTS WHEN COUNTING CYCLES OF A SINE-WAVE SIGNAL

In the common case in which the input approximates a sine-wave signal having a frequency between 10 cps and 2.1MC, and when the object is merely to generate one pulse for each cycle without regard for the precise time at which a pulse occurs, the ATTENUATION and TRIGGER VOLTAGE controls may be set as follows:

1. Couple the input signal to the INPUT jack. Input sensitivity is 100 mv rms (0.3 volts peak-to-peak). Input impedance is 10 megohms.
2. Place FUNCTION switch at COUNT and press manual reset button. (SLOPE switches may be in any position.)
3. Rotate the TRIGGER VOLTAGE control slowly from one extreme to the other while the ATTENUATION control is at each of the three positions on the AC side (1, 10 & 100). Notice that the instrument will count steadily over a certain arc of TRIGGER VOLTAGE positions for each ATTENUATION setting. Choose the highest ATTENUATION position at which counting will continue over an arc of at least 45 degrees rotation of the TRIGGER VOLTAGE control.
4. Position the TRIGGER VOLTAGE control at the center of the arc over which counting occurs.

EFFECT OF INPUT CONTROLS

Figure 3a is a block diagram of an input trigger channel.

The impedance at the INPUT jack is 10 megohms in parallel with 35 micromicrofarads. This impedance may be reduced to match the source or to avoid capacitive pickup by attaching a "T" connector to the jack and adding resistors or capacitors in parallel. The input sensitivity is

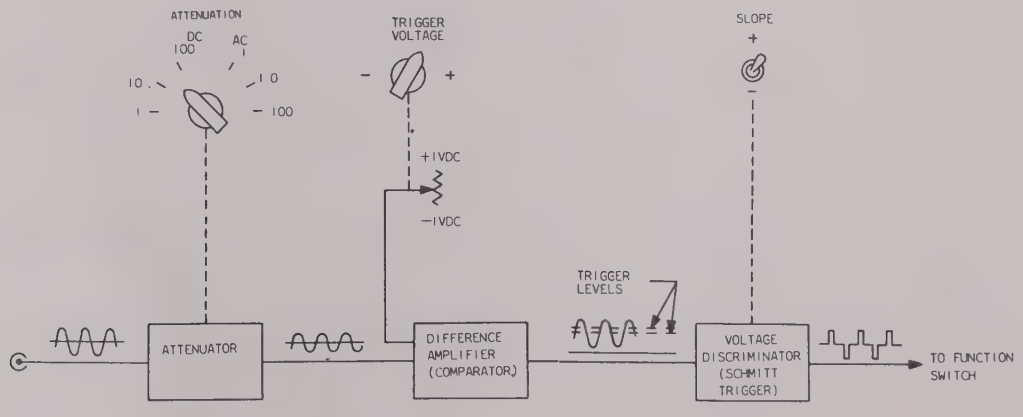


Figure 3a

equal to 0.3 volts peak-to-peak times the factor to which the ATTENUATION control is set. The input circuitry will withstand a signal as strong as 500 volts peak-to-ground without damage.

The attenuator divides the voltage introduced at the INPUT jack by the factor indicated by the ATTENUATION control. When the control points to a factor on the side labelled "DC", the total INPUT signal is attenuated and passed on. When the control points to a factor on the side labelled "AC", the d-c component is removed and only the a-c component is attenuated and passed on. Frequencies as low as 1 cps will be passed in the "AC" positions.

Figure 3b shows how the varying voltage of the attenuated signal triggers channel output pulses. A pulse is produced each time the instantaneous voltage of the attenuated signal passes through the "positive-going trigger voltage" starting from a value more negative than the "negative-going trigger voltage". Another pulse is produced each time the instantaneous attenuated voltage passing from a value more positive than the "positive-going trigger voltage". When the SLOPE switch is at "+", only pulses triggered by positive-going voltage excursions affect the succeeding circuitry. With the SLOPE switch at "-", only pulses triggered by negative-going excursions are effective.

The two trigger voltage levels (positive-going and negative-going) are always separated by 0.3 volts, the effective hysterisis. Because a voltage excursion must travel through both levels to trigger a pulse, the sensitivity of the channel to the attenuated signal is 0.3 volts peak-to-peak. The trigger voltage levels are raised or lowered simultaneously (maintaining 0.3-volt separation) when the TRIGGER VOLTAGE control is varied. This control will vary the levels from roughly -1 volt to +1 volt. Referring to figure 2, notice that the TRIGGER VOLTAGE control actually raises or lowers the d-c level of the input to the voltage discriminator. However, this action has the effect of raising or lowering the trigger voltage levels at the input to the difference amplifier.

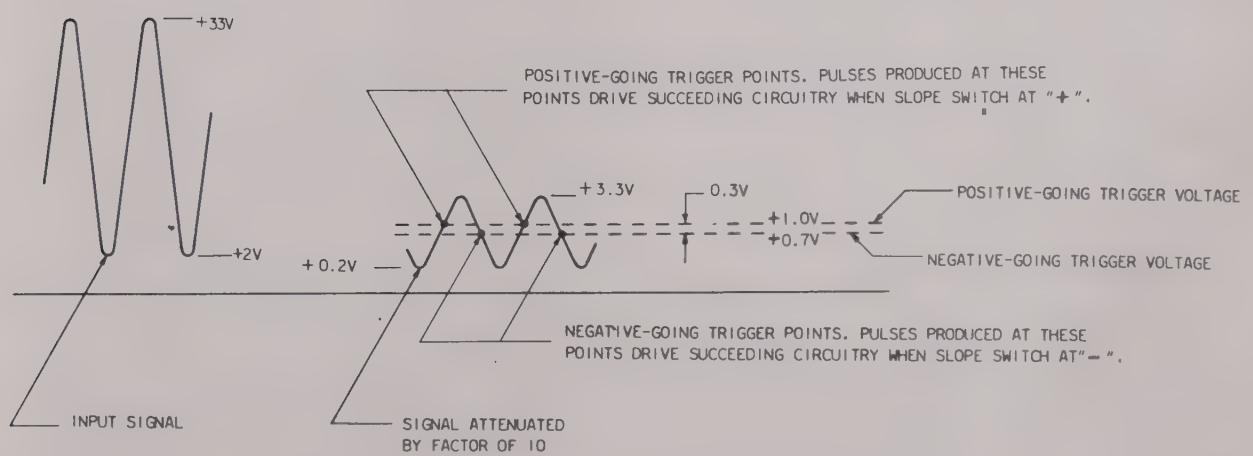

+33V
+2V
+0.2V
POSITIVE-GOING TRIGGER POINTS. PULSES PRODUCED AT THESE POINTS DRIVE SUCCEEDING CIRCUITRY WHEN SLOPE SWITCH AT "+".
+3.3V
0.3V
+1.0V
+0.7V
POSITIVE-GOING TRIGGER VOLTAGE
NEGATIVE-GOING TRIGGER VOLTAGE
NEGATIVE-GOING TRIGGER POINTS. PULSES PRODUCED AT THESE POINTS DRIVE SUCCEEDING CIRCUITRY WHEN SLOPE SWITCH AT"-".
INPUT SIGNAL
SIGNAL ATTENUATED BY FACTOR OF 10

Figure 3b

The purpose of the input trigger channel is to produce a reliable pulse output representing that part of the input signal in which the operator is interested. This is achieved only when the ATTENUATION and TRIGGER VOLTAGE controls are properly adjusted. Before attempting to adjust the controls, it is best to visualize the input waveform, noting the shape, a-c amplitude and d-c level. The effect of various control settings is then relatively easy to calculate. Referring to figure 3, notice that:

1. If the attenuated signal is small peak-to-peak, the trigger voltage levels may be set so high or so low that no pulses are produced. In figure 3, for example, if the "positive-going trigger voltage" were set at -0.5 volts (thus placing the "negative-going trigger voltage" at -0.8 volts), the attenuated signal with peaks at +0.2 and +3.3 volts would not intersect either trigger voltage level.
2. If the attenuated voltage variations ride on a d-c level, they may not come within the trigger voltage range. In figure 3, again, if the input signal were not attenuated (or a-c coupled) the negative peak at +2 volts would not intersect any possible trigger voltage level.
3. Modulation or variations in the d-c level of the attenuated signal are least likely to subtract pulses if the trigger voltages are set about halfway between the peaks of the signal.
4. Extraneous signals (noise, hum, modulation, drift, etc.) have the least effect on the time at which a pulse occurs when the channel triggers on a steep slope of the waveform.
5. Noise below 0.3 volts peak-to-peak will not trigger extraneous pulses. Consequently, attenuating a signal carrying a given percentage of noise may eliminate the effect of the noise. For example, 1 volt peak-to-peak noise on a 6 volt peak-to-peak signal will trigger extraneous pulses. If the signal is attenuated by a factor of 10, the resulting 0.6 volt p-p signal will still trigger desired pulses dependably, while the resulting 0.1 volt p-p noise is well below the sensitivity of the channel.
6. Attenuating the input signal
   (a) Reduces the slope at all points
   (b) Shifts the a-c component nearer ground if it rides on a d-c level.
   (c) Increases the minimum peak-to-peak variations necessary to trigger pulses (measured at the INPUT jack) from 0.3 volts to 3 or 30 volts.
   (d) Increases the range of possible trigger voltage setting on the input signal from ±1 volt to ± 10 volts or ± 100 volts.

Adjustment of ATTENUATION and TRIGGER VOLTAGE controls should be made keeping the above characteristics in mind. When using any regular periodic input signal, consistent E/UT or PERIOD readings are a good indication that the controls are properly adjusted.

The point on an input waveform where the input channel triggers may be seen on an oscilloscope. Observe the control-grid input of the voltage discriminator in the input channel (V303, pin 2). The waveform which appears is the amplified input signal together with small "notches" created on each slope as the channel triggers. Rotating the TRIGGER VOLTAGE control will cause these notches to move up and down the waveform. See "Typical Waveforms" for a sample display. Some information about the position of the trigger voltage relative to the signal may be extracted from the instrument itself. The trigger voltages may be varied between the positive and negative peaks of an attenuated signal whose peaks lie within the range of -1 to +1 volts. As the trigger voltage pass beyond the signal peaks, the pulse output of the channel will cease and these positions of the control may be noted.

MEASURING FREQUENCY

The frequency of a regular sine-wave signal can be measured either directly under E/UT or E/UT x 10 Operation or indirectly by measuring the period of the signal and calculating the frequency. The direct method is simpler and will ordinarily be used except when measuring a low frequency. signal with extreme accuracy. See the "ACCURACY" section of this manual for the accuracy limitations of events-per-unit-time operation.

TEST Operation

To put the instrument in operation connect the power cord and place the POWER switch in the position which lights the green indicator above it. After a two minute warm-up, test the instrument for proper operation:

1. Turn DISPLAY Time to a point near the extreme counter -clockwise position to obtain a short display time and automatic operation.
2. Turn FUNCTION switch to TEST.
3. Rotate TIME switch to each position starting with the 10^{-5} seconds setting on the Model 7160 or the 10^{-4} seconds setting on the Model 7150. In either case this should give a reading of 10. As the switch is turned clockwise, other settings should read successively 100, 1000 or 999, 10, 000 or 9, 999, 100, 000 or 99, 999 and (on the Model 7160 only) 1, 000, 000 or 999, 999.

Note that the DISPLAY time is infinite at the extreme clockwise position of the control. In this position, the instrument must be reset manually.

E/UT (Events-Per-Unit-Time) Operation

At the E/UT position of the FUNCTION switch the unit counts the input to the Trigger Channel between start and stop signals separated by a precise time interval. This setting may be used to measure the frequency of a signal or the number of events occuring within a selected time interval. The major components are connected as diagramed in Figure 4a.

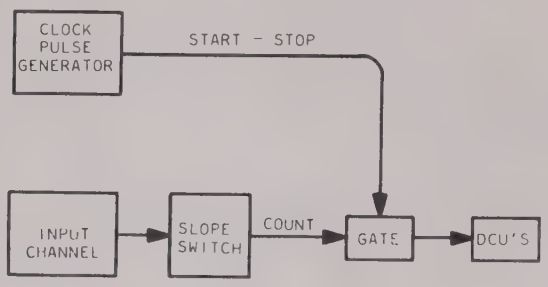


Figure 4a

To make a measurement proceed as follows:

1. Connect input to INPUT jack. (See "COUNTER INPUT ADJUSTMENTS" above.)
2. Rotate the FUNCTION switch to the E/UT position. In this position the START SLOPE switch determines the polarity of the voltage excursion which triggers count pulses. It may be at either position.
3. Set the TIME switch at the time interval over which events are to be counted.
4. Adjust the DISPLAY time control to a position at which the count on the lighted DCU's may be read conveniently.
5. To obtain a reading in events per second, divide the reading on the lighted DCU's by the number to which the TIME switch is set.

SCAN Operation

The interval during which events are counted may be extended to any multiple of the 1 second counting period. Consider the total counting interval desired as N counting periods. Then proceed as follows:

1. Connect input to INPUT jack. (See "COUNTER INPUT ADJUSTMENTS" above.)

2. Turn DISPLAY TIME control fully clockwise.
3. Place FUNCTION switch at E/UT.
4. Turn the TIME switch to 1 to obtain a one-second period.
5. Press the RESET button. Within 1 second the instrument will begin a normal counting period.
6. Before the end of the 1-second period turn the FUNCTION switch to the SCAN position and begin timing N minus 1 counting periods with a stopwatch.
7. At the end of N minus 1 periods turn the FUNCTION switch back to E/UT.
8. When the instrument stops counting, read the count.

PERIOD Operation

At the PER position of the FUNCTION switch the unit measures the time interval between consecutive voltage excursions through a selected level at the INPUT jack. This setting may be used to measure the period of a wave or the width of a pulse. The major components are connected as in Figure 4b.

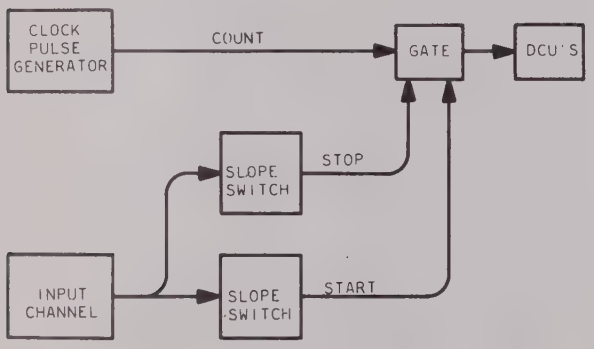


Figure 4b

To make a measurement proceed as follows:

1. Connect the wave or pulse source to the INPUT jack. (See "COUNTER INPUT ADJUSTMENTS" above.)
2. Rotate the FUNCTION switch to PERIOD. At this position the START SLOPE switch selects the polarity of the voltage excursion which begins the timing period. The STOP SLOPE switch selects the polarity of that which ends the timing period.
3. Therefore,
   (a) When measuring the period of a wave, set both SLOPE switches to "+" or both to "-".
   (b) When measuring the width of a positive pulse, set the START SLOPE to "+" and the STOP SLOPE switch to "-".
   (c) When measuring a negative pulse, set the START SLOPE switch "-" and the STOP SLOPE switch to "+".
3. Rotate the TIME switch to the desired unit of time measurement. For example, at the 10^{-4} position the time measurement appears in ten-thousandths of a second. The smaller the time unit chosen, the more accurate the reading.
4. Adjust the DISPLAY time control to a position at which the count on the lighted DCU's may be read conveniently.
5. To obtain a reading in seconds, multiply the count on the DCU's by the factor to which the TIME switch is set.

COUNT Operation

The unit counts the input to the channel during the period the FUNCTION switch is in the COUNT Position.

1. Connect input to channel. (See "COUNTER INPUT ADJUSTMENTS" above.)
2. Turn FUNCTION switch to OFF.
3. Depress manual RESET button.
4. Twist FUNCTION switch to COUNT to begin counting.
5. Twist FUNCTION switch to OFF to stop counting.

USING AN EXTERNAL REFERENCE FREQUENCY

An external reference frequency may be substituted for the internal oscillator signal. The substituted signal must have an amplitude of 3 volts rms into a 7K load. Its frequency may be as high as 100KC in the case of the Model 7150 or as high as 1MC in the case of the Model 7160. Couple the signal to the FREQ. jack at the rear of the counter and place the EXT-INT switch at EXT.

NOTE: The .01 μf capacitor (C401) connected between the FREQ. jack and the input circuit used for this operation is not large enough to pass frequencies lower than 10KC. If the external signal frequency is lower than 10KC, jumper this capacitor and connect a larger capacitor between the signal source and the FREQ. jack.

The shaper stage of the clock pulse generator is used as the input trigger channel for the signal introduced at the FREQ. jack. Adjust the input trigger voltage of this channel with the SHAPER LEVEL control located on the top side of the counter chassis. Rotate this control to find the limits of the range in which the instruments counts. Set the control at the center of this range.

REMOTE CONTROL OF OPERATING CYCLE

The counter can be controlled from a remote location so that it will not reset and begin another count until desired. Set the DISPLAY time control at a minimum and string a lead from the remote location to Pin 40 of the DIGITAL RECORDER socket. As long as this lead is grounded the counter will not reset. If a count is complete, then within 40 milliseconds after the lead is ungrounded the counter will have reset and be ready to start counting when a start pulse appears. As soon as the counter has reset, the lead may be grounded again or left ungrounded. It will not affect the operating cycle until the time arrives for the next automatic reset. At that time it must be grounded again to prevent reset.

ACCURACY

Measurements are subject to four important sources of error.

1. Counts missed or added as the Gate opens and closes.
2. Clock signal inaccuracy.
3. Errors in the time a start or stop pulse is triggered.
4. Counts missed because they occur during the resolution time of the counting circuits.

1.

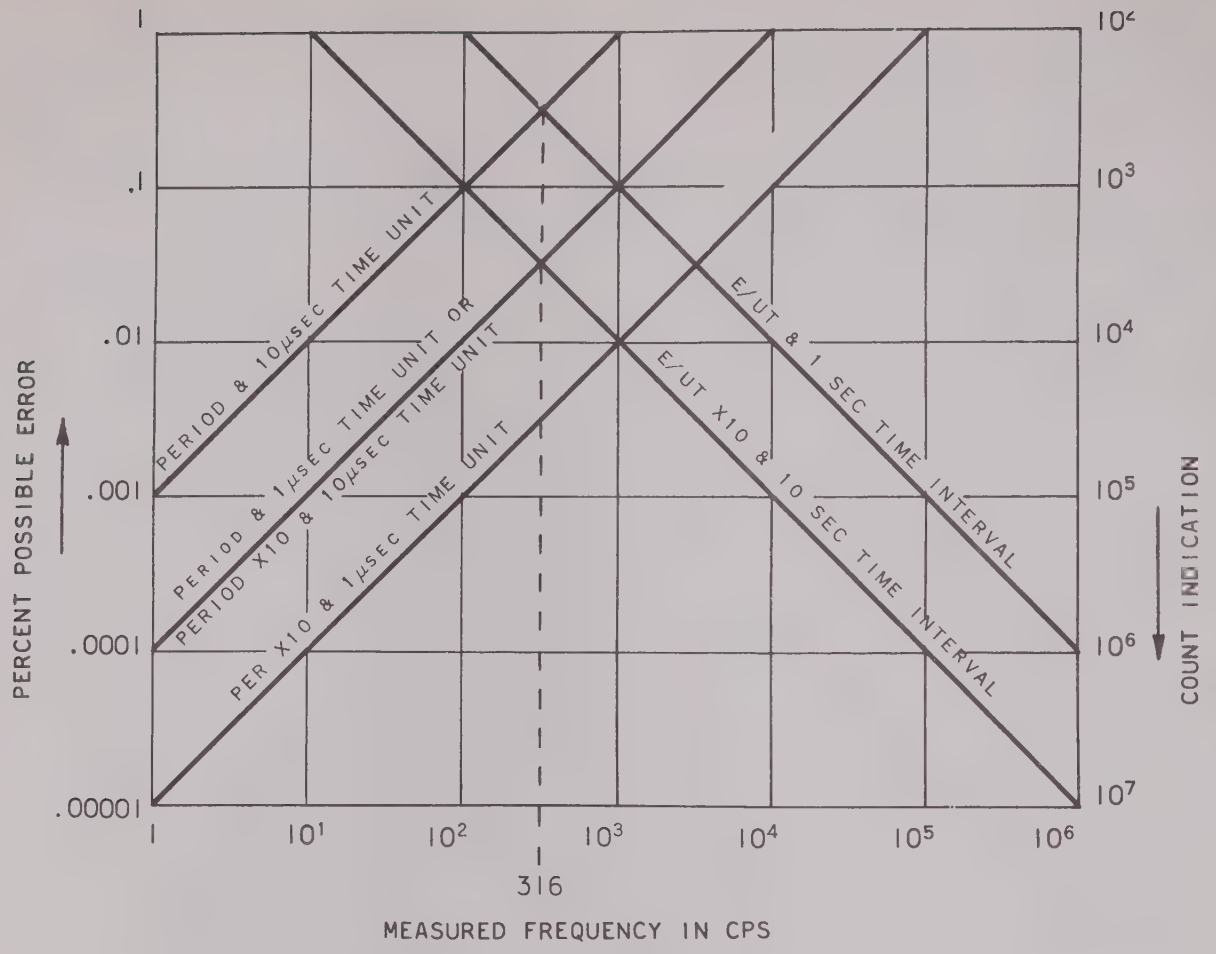
Pulses which occur simultaneously with the opening or closing of the Gate may or may not be counted. This causes all measurements to vary plus or minus one count. The following equation defines the possible error introduced.

$$\text{(1) Max. \% error} = \frac{1}{\text{Count Indication}} \times 100.$$

Notice that measurements set up to yield the highest count indication will be most accurate.

The frequency of a sine wave signal can be measured directly by counting events-per-unit-time or indirectly by measuring the length of one period and calculating the frequency. Higher frequencies yield the highest count indication when measured directly, that is, using the E/UT function. Lower frequencies produce the highest indication when rapid time signals are counted over one period - that is, using the PERIOD function.

On the Model 7160 frequencies above 1KC produce the highest count indication when measured using the E/UT function and a 1-second time interval; frequencies below 1KC yield the highest count when measured with the PERIOD func-



NOTE: THE 1μSECOND TIME UNIT IS NOT AVAILABLE ON THE MODEL 7150. THE "TIMES TEN" (X10) FUNCTIONS AND THE AUTOMATIC 10-SEC INTERVAL ARE POSSIBLE ONLY USING THE B MODIFICATION OF THE EPUT METER.

Figure 5 Error due to ± 1 Count Limitation

tion and a 1 μsecond unit of time measurement. The accuracy achieved using alternative functions at various frequencies is graphically illustrated in Figure 5. Note that the curves for E/UT (1-second interval) and PERIOD (1 μsec time unit) cross at 1KC. This frequency cannot be measured with a possible error less than .1%. Frequencies above and below may be measured with greater accuracy.

The smallest unit of time available on the Model 7150 is 10 μseconds. Lower frequencies are most accurately measured using the PERIOD function and this time unit. Notice on Figure 5 that this curve crosses the E/UT curve at 316 cps. Therefore on the Model 7150 frequencies above 316 cps are most accurately measured using E/UT and a 1-second time interval whereas frequencies below 316 cps are best measured using the PERIOD function and the 10 μsecond unit of time. 316 cps cannot be measured with

a possible error less than 0.3%, but lower and higher frequencies may be measured more accurately.

2. All measurements requiring a time signal (i.e. all measurements except COUNT) are subject to an additional error introduced by variations in the oscillator frequency. The oscillator frequency in the Model 7160 is stable to 1 part in 10^6 per day, so it can cause a maximum error of only .0001%. The oscillator in the Model 7150 is stable to 1 part in 10^5 per day. It causes a maximum error of .001%.

3. Measurements using a external signal to trigger start and stop pulses (i.e. PERIOD) may be subject to a further error caused by pulses which are triggered too soon or too late. Refer to Figure 6 which illustrates what occurs during a simple period measurement.

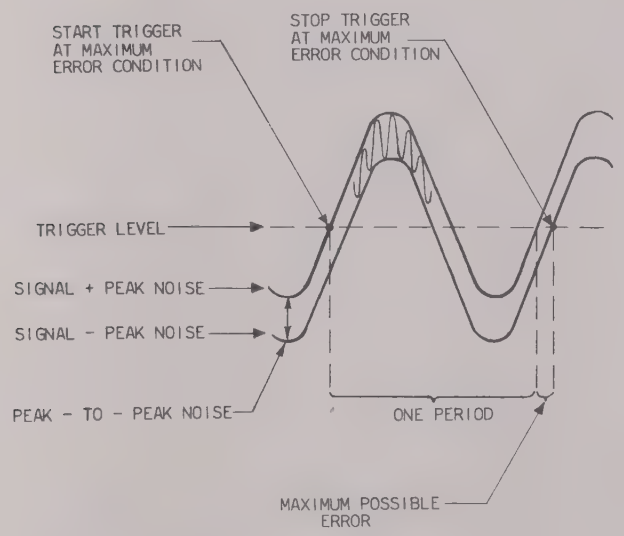

START TRIGGER AT MAXIMUM ERROR CONDITION
STOP TRIGGER AT MAXIMUM ERROR CONDITION
TRIGGER LEVEL
SIGNAL + PEAK NOISE
SIGNAL - PEAK NOISE
PEAK - TO - PEAK NOISE
ONE PERIOD
MAXIMUM POSSIBLE ERROR

Figure 6 Effect of Noise on Accuracy of Period Measurements

Consider the total signal as an ideal signal intended to trigger the input channel plus a noise signal. The noise voltages added or subtracted from the ideal signal may trigger a pulse before or after the instant at which counting should begin or end. The maximum error in the time of triggering will be proportional to the noise amplitude and inversely proportional to the slope of the ideal signal at the trigger level. Expressed mathematically,

$$(2)\quad t\ (\text{secs}) = \frac{V_n\ (\text{volts})}{S\ (\text{volts/sec})}$$

where t = Max. error in trigger time

V_n = peak-to-peak noise

S = slope of ideal signal at trigger level

The total noise (V_n) is equal to that carried by the input signal after attenuation plus that internally generated by the input channel. The internal noise (which takes the form of amplifier drift, trigger level jitter, line frequency pick-up, etc) is not more than 300 microvolts. Note that as the amplitude of of the input signal is increased, S in equation (2) becomes larger and the internal noise causes less error.

The percentage error may be calculated by dividing the error in trigger time by the counting period and multiplying by 100. In the common case of a period measurement of a sine wave triggering at its zero crossover value:

$$(3)\quad \text{Max. \% error} = \frac{V_n\ (\text{volts})}{V_s\ (\text{volts}) \times \pi} \times 100$$

where V_n = peak-to-peak noise

V_s = peak-to-peak signal

The maximum percent error of a PERIOD x 10 measurement is one-tenth the value given in equation (3).

The total error due to the three causes mentioned above is equal to the sum of the separate errors.

Total Max. percent error equals:

$$\frac{100}{\text{Count Indication}} + \begin{matrix}.0001\ (7160) \\ \text{or} \\ .001\ (7150)\end{matrix} + \text{Percent error due to noise}$$

$\frac{100}{\text{Count Indication}}$ + (.0001 (7160) or .001 (7150)) + Percent error due to noise

↓ If E/UT or PERIOD

↓ If PERIOD

4. Another source of error becomes important when random events are counted. One such event may occur immediately after another, before the counting circuits are fully recovered and prepared to register it. The second event will not only fail to cause a count but its effect on the circuitry may cause a third event to fail to register also. Formulae for calculating the counting error due to this effect may be found in "Application of Probability Theory to Nuclear Particle Detection", L. J. Rainwater and C. S. Wu, Nucleonics, October 1947. The minimum time which must elapse between events if both are to be counted is called resolution time of the instrument. The Model 7160 has a resolution time of .8 μseconds. The Model 7150 has a resolution time of 5 μseconds.

AUXILIARY CONNECTORS

DIGITAL RECORDER Jack. Each DCU generates a 4-line code representing the digit it is displaying. These lines are collected at the DIGITAL RECORDER socket at the rear of the instrument. The Model 1452 Digital Recorder plugs directly into this socket. The socket also makes mutual control connections between the counter and the recording device.

In the four-line code "0" represents a voltage 15 or more volts negative of ground; "1" represents a voltage at ground or positive of ground.

DECIMAL DIGIT REGISTERED	FOUR - LINE BINARY CODE			
	1st Binary Stage	2nd Binary Stage	3rd Binary Stage	4th Binary Stage
0	0	0	0	0
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	0	1	1	0
5	1	1	1	0
6	0	0	1	1
7	1	0	1	1
8	0	1	1	1
9	1	1	1	1
No Digit	0	0	1	0

	PIN NO. ON DIGITAL RECORDER SOCKET			
	1st Binary Stage	2nd Binary Stage	3rd Binary Stage	4th Binary Stage
Highest order digit read*	Pin 4	Pin 3	Pin 2	Pin 1
2nd highest order digit	8	7	6	5
3rd highest order digit	12	11	10	9
4th highest order digit	16	15	14	13
5th highest order digit	20	19	18	17
6th highest order digit**	24	23	22	21

* On instruments featuring "times ten" positions of the FUNCTION switch no read-out pins are provided for the left-most DCU, which displays the highest order digit during some measurements. On these instruments the highest order digit represented by a 4-line code is in the front-panel column second from left.

** On instruments containing only five read-out DCU's pins 21 thru 24 are permanently wired to produce the "no digit" code which is "0010".

Pin 39 carries a control signal from the counter. This pin is negative during the display period and positive from reset until the end of the next counting period.

Pin 40 is the "inhibit reset" line. When this pin is grounded the counter cannot reset.

Pin 38 is grounded. Pins 25 thru 37 are not connected to anything.

TIME Jack. The output signal of the clock-pulse generator is available at this jack. The signal consists of positive pulses 2.5 volts in amplitude. The positive transients are accurately spaced at the interval indicated by TIME switch. These transients are recommended for external use as a clock signal. The negative transients occur at the same frequency but are not so accurately spaced. The output impedance is 330 ohms.

FREQ Jack. A sine-wave signal at the oscillator frequency is available at this jack when the EXT-INT switch is at INT. The signal is 10 volts peak-to-peak out of 3000 ohms. When the EXT-INT switch is at EXT., an external signal can be introduced at this jack to substitute for the oscillator signal as described under "GATE Operation".

SCOPE Jack. This jack is connected thru 220K to the suppressor grid of the gate tube. The voltage on the grid determines whether the gate is "open" or "closed". The voltage at the jack is about ground level when the gate is open and about -22 volts with respect to ground when the gate is closed. If the waveform of a signal generating start-stop pulses is displayed on an oscilloscope, the signal at the SCOPE jack may be used to blank the scope during the period the gate is closed. The scope will then display the portion of the wave form whose length is being measured.

ACCESSORY Jack. This socket provides connections to +120 VDC regulated at 10 ma, -110 VDC at 15 ma, +190 VDC at 20 ma and 6.3 VAC at 2 amperes. These supplies may be used to power auxiliary equipment such as transducers. The power supply schematic shows at which terminal each supply is available.

3 Circuit description

NOTE: It is intended that the reader refer frequently to relevant schematic diagrams while reading the material in this section. The Decimal Counting Units are described in an appendix.

GATE & CONTROL CIRCUITRY

The Gate and control Circuitry receive three pulse inputs from the FUNCTION switch (S201): pulses to be counted, start pulses and stop pulses. Pulses to be counted go from Deck G to the signal grid of the Gate tube (V204). The plate of this tube is coupled to the first of the cascaded DCU's. During the period its suppressor grid is at ground the tube amplifies the grid signal and drives the DCU's. In this state the Gate is "open". When the suppressor grid is below -10 volts, the tube is cut off and the Gate may be considered "closed".

The "open-close" voltages on the Gate tube suppressor grid are generated at the right plate of the Control Binary (V203). V203 is a conventional "flip-flop" circuit. Such a circuit has two stable states: left half conducting, right half cut off; and right half conducting, left half cut off. Input pulses or transients applied at various points on the circuit will trigger it back and forth between the two states. When the right half of V203 is conducting, the right plate is 30 volts negative. A negative start transient from the Start Binary, applied at the left plate of V203 and coupled through C210 to the right grid, triggers V203 to its other stable state. In this state the right half is cut off and the right plate rises above ground permitting the Gate tube to conduct.

When a negative stop pulse from Deck E of the FUNCTION switch reaches the left grid of V203 through the diode V201B, V203 is triggered back to the state which holds the Gate closed.

The Start Binary is also a "flip-flop" circuit. It produces a negative start transient at its right plate each time that half begins to conduct. Its left grid is coupled to Deck C of the FUNCTION switch through the diode V201A and C201. When the left half is conducting a negative start pulse at the grid triggers a change to the other stable stage producing the output transient. Further negative pulses at the left grid have no effect since that half is already cut off.

When the instrument is ready to begin a counting period the right half of the Control Binary and the left half of the Start Binary are conducting and the Gate is closed. Negative stop pulses received at the left grid of the Control Binary have no effect since this half is cut off. The following sequence occurs. (Refer to Figures 7 & 8).

Time (1) A start pulse passes through the injection diode V201A and triggers the Start Binary which in turn triggers the Control Binary to a state which opens the Gate. The DCU's then

count and indicate the number of pulses reaching the Gate.

Time ② A stop pulse triggers the Control Binary to a state which closes the Gate.

At this point, if the instrument is set to operate automatically, the reset circuitry begins to function. The reset control voltage appears at the junction of CR201 and CR203. Its value is determined by the combined effect of the voltage on the right plate of the Start Binary and that on the right plate of the Gate Control Binary. At the close of a counting period (and only then) both these plates are negative. The resulting negative voltage at the junction is applied to the input grid of the Reset Generator through R239.

The Reset Generator (V205) is a two stage amplifier. The first stage (the left half) is a voltage amplifier. The second stage is a cathode follower. The Reset Generator performs two functions. It amplifies the reset control voltage at time ② and it produces a reset pulse upon receiving a signal from the Reset Control at time ③. The negative reset control voltage is amplified, inverted and coupled from the output cathode to the DISPLAY time potentiometer (R247) through R244, CR206 and S204. The positive charge at R247 leaks onto C216. C216 is coupled to the input grid of the Reset Control (V206) through S205B. When this grid rises above a certain voltage, V206 generates an output pulse which initiates step ③, the reset action.

The Reset Control is a monostable mutlivibrator. In its stable state the right triode is conducting and the left triode is cut off. When the left grid becomes sufficiently positive, that half begins to conduct and the right side is cut off momentarily by a negative pulse produced at the left plate and coupled to the right grid by C218. The output is a positive pulse at the right plate.

This positive pulse is coupled through R236 and R239 to the input grid of the Reset Generator producing a negative transient at the plate of the first stage which resets all the DCU's and Start Binary. The positive pulse from the Reset Control is also coupled to the cathode of the Start Binary injection diode by R212, C203 and R209. The positive charge on the cathode prevents negative start pulses from reaching the Start Binary until all reset transients have decayed. At time ④, about 15 milliseconds after the reset pulse, the control circuitry is ready to accept another start pulse.

NOTE: When the counter is equipped with the Model 1452 Digital Recorder, the sequence of operations described above is interrupted briefly. A relay in the recorder grounds the input to the DISPLAY time potentiometer from the end of the counting period (time ②) until the recorder has collected count information from the DCU's. (See Figure 9). The connection to the recorder is made through pin 40 of J202.

When the DISPLAY time control is turned fully clockwise the input connection to this potentiometer is broken by S204 and the automatic reset action will not occur. The DCU's hold the accumulated count until the manual RESET button is depressed. Depressing this button actuates S205A and S205B. S205A connects the -110 volt supply to the Reset Generator input grid. S205B connects C216 to the output cathode of the Reset Generator which is then at a high positive voltage. When the button is released the positive charge on C216 flows onto the Reset Control grid and initiates the same reset action that occurs under automatic operation.

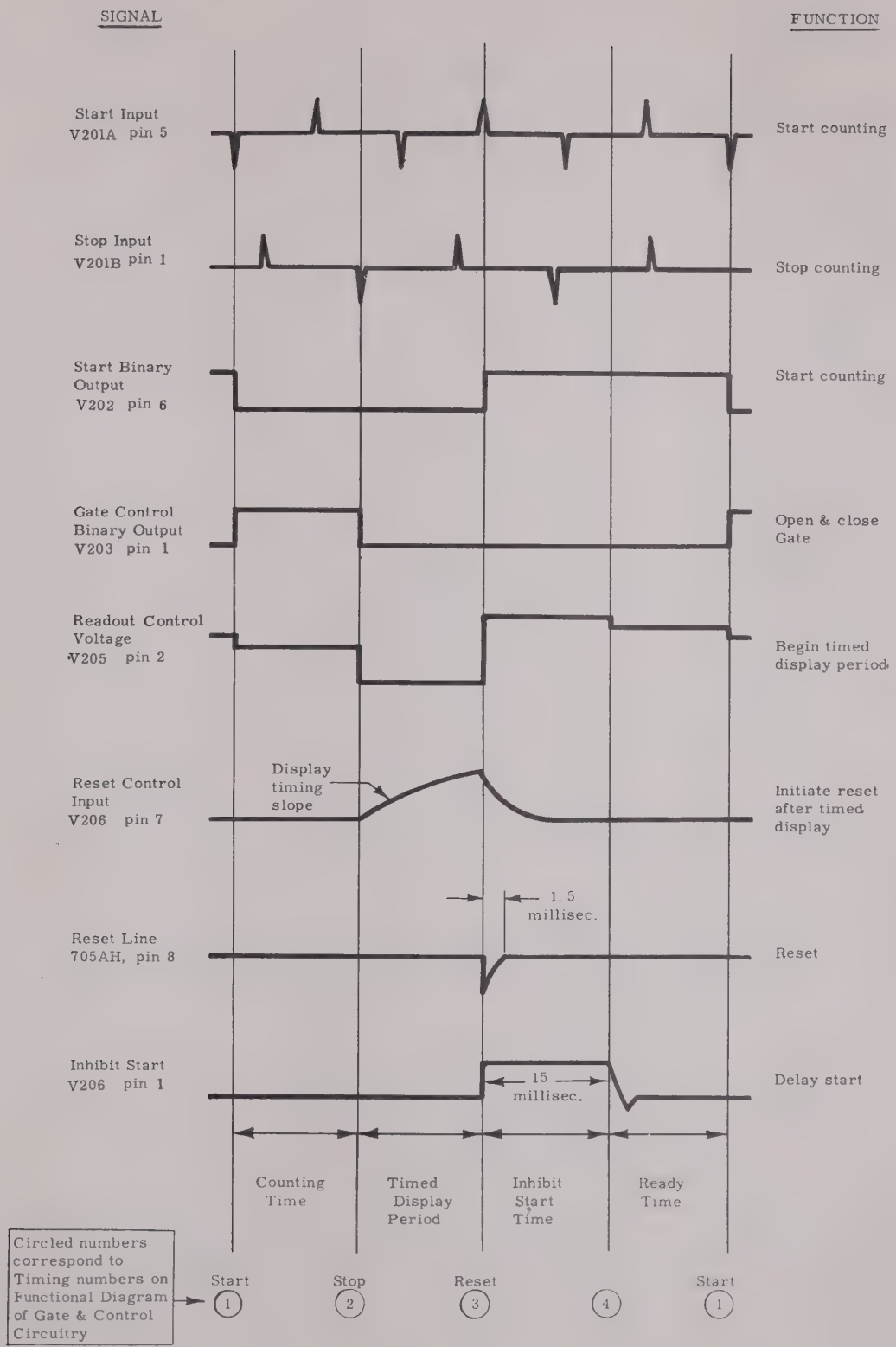
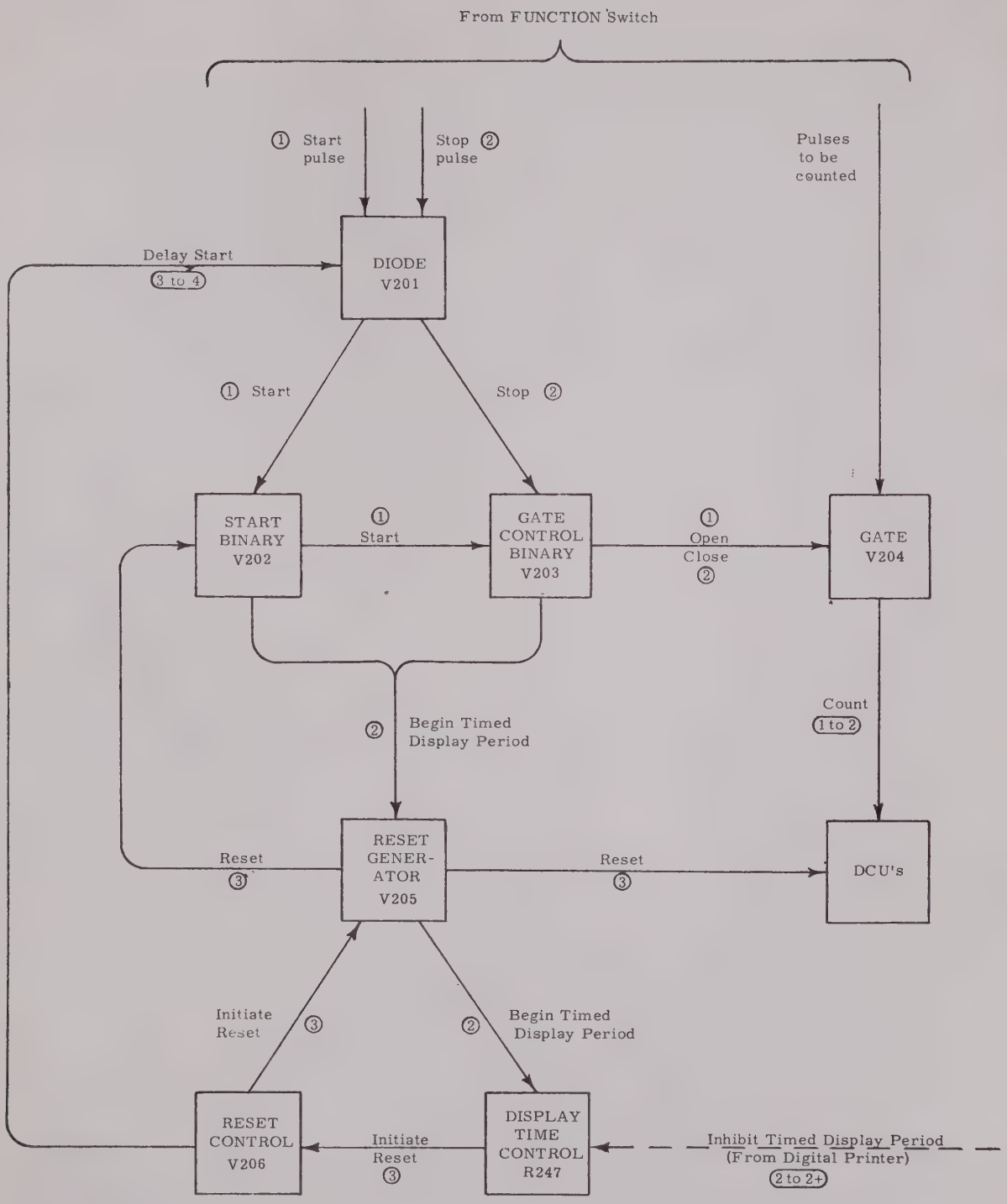


Figure 7 Control Circuit Timing Diagram

WHEN COUNTER IS NOT EQUIPPED WITH DIGITAL PRINTER



NOTE: Circled numbers indicate time of operation as labeled on the Timing Diagrams.

Figure 8 Functional Diagram of Gate and Control Circuitry

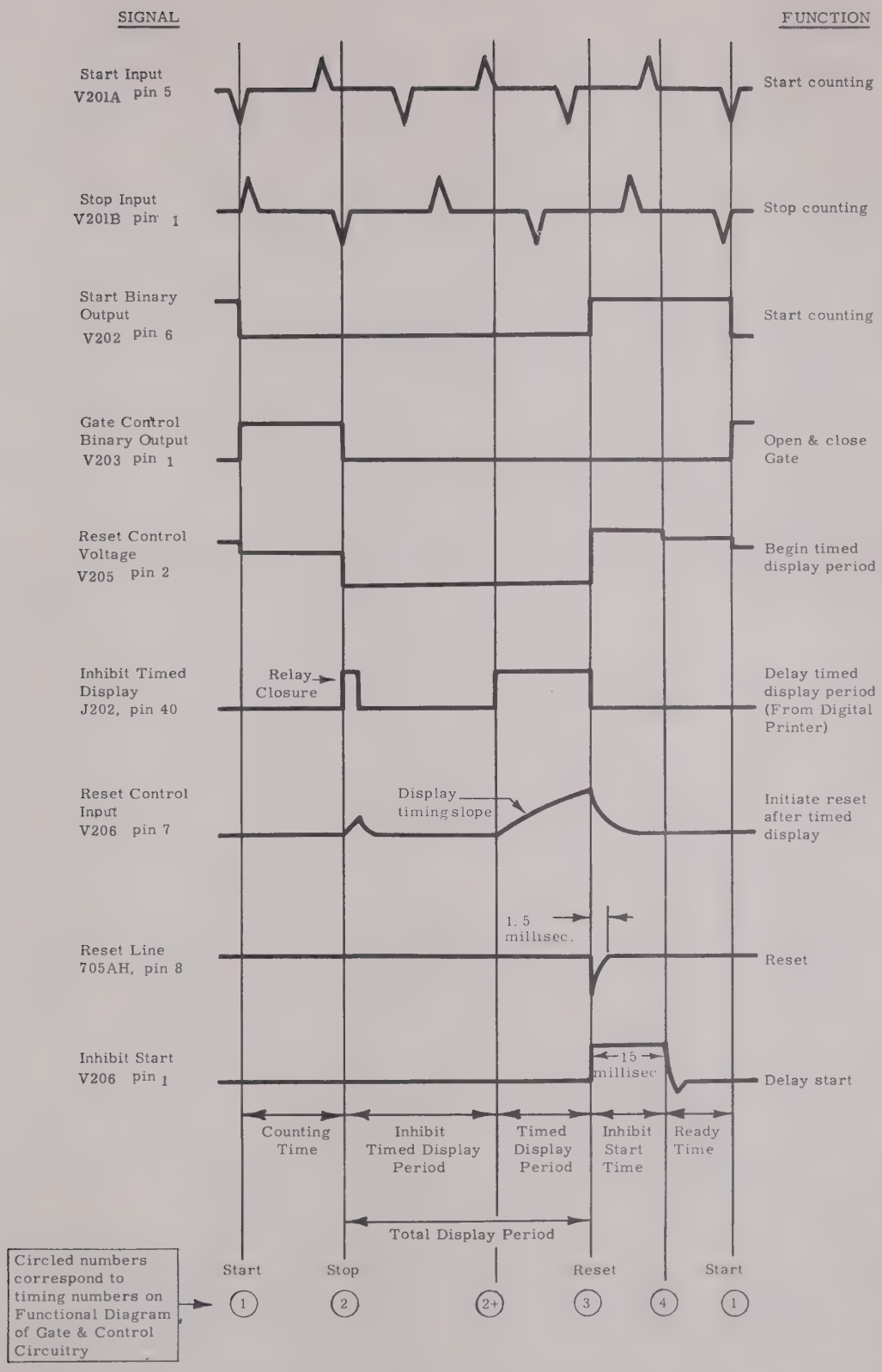


Figure 9 Control Circuit Timing Diagram

WHEN COUNTER IS EQUIPPED WITH DIGITAL PRINTER

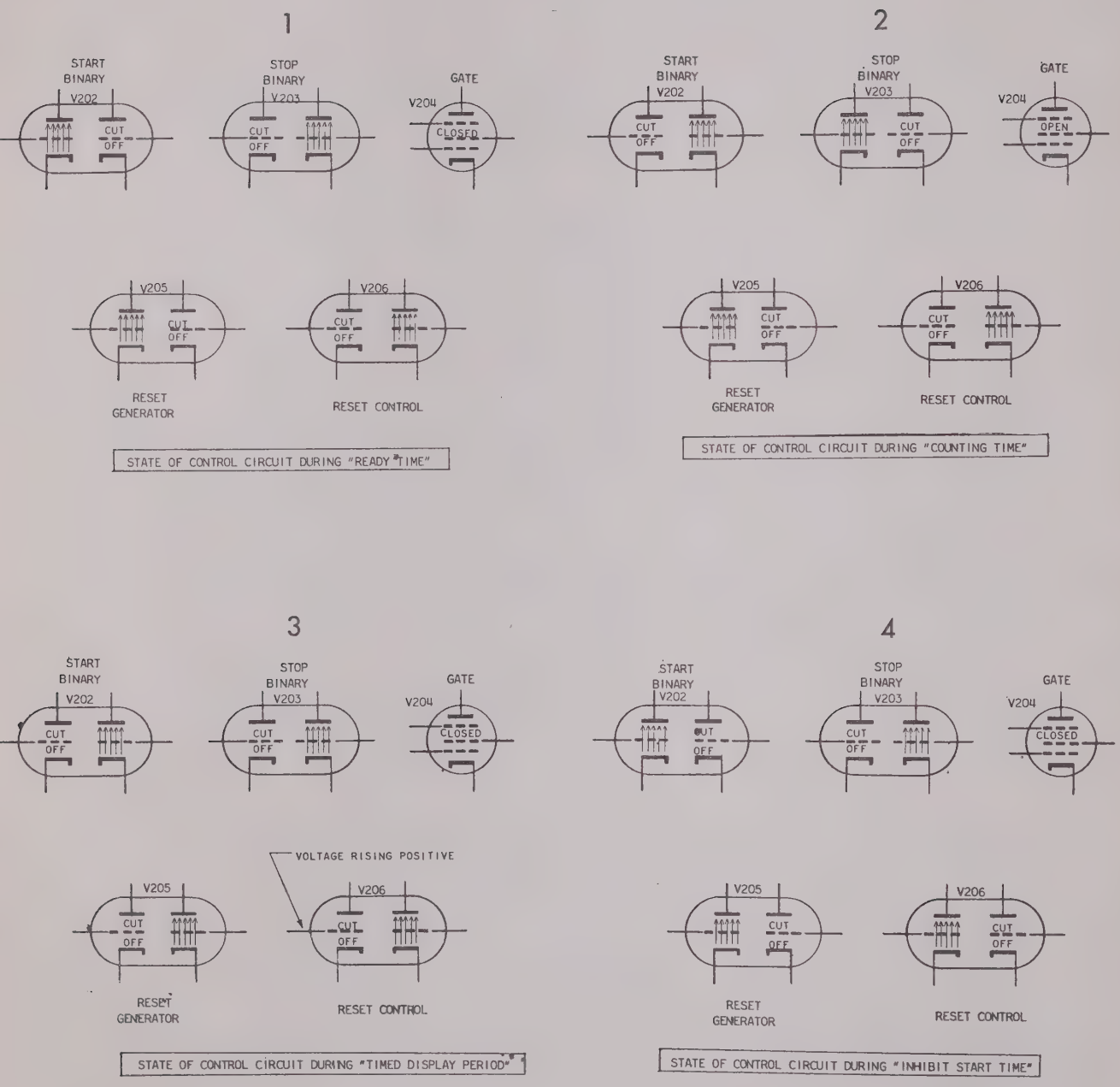


Figure 10 Tube States During the Operating Cycle

INPUT TRIGGER CHANNEL

The input trigger channel produces an output pulse each time the attenuated input signal passes a selected voltage level. The output is independent of input waveform. The channel consists of a Schmitt trigger voltage discriminator preceded by a two stage comparator amplifier. The input channel is preceded by an attenuator, which divides the input voltage by 1, 10 or 100 according to the position of the ATTENUATION control. The input impedance at all positions is about 10 megohms in parallel with 40 μμf. When the ATTENUATION control is at an AC position a .01μf capacitor (C201) is inserted in series between the INPUT jack and the attenuator.

The comparator amplifier has two stages. The first is a difference amplifier whose output is proportional to the input voltage on the grid of V301A minus a selected constant voltage on the grid of V301B. The TRIGGER VOLTAGE potentiometer (R318) varies the voltage on the grid of V301B between -1 and +1 volts. The second stage (V302) amplifies the double-ended signal received from V301 and converts it to a single-ended low impedance output at the left hand plate. This plate is connected to the input grid of the discriminator.

The voltage discriminator (V303) produces an output pulse each time the input voltage on its left-hand grid passes through a fixed voltage level (about +60 volts). Consider the input to this circuit as an a-c triggering signal superimposed on a d-c level. The a-c signal is an amplified reproduction of the voltage variations on the grid of V201A, that is, the attenuated input. The d-c level is determined by the voltage on the grid of V301B, a voltage set by the TRIGGER VOLTAGE potentiometer. As the TRIGGER VOLTAGE control is rotated toward "+", the d-c level is lowered and the discriminator triggers at a higher instantaneous voltage of the a-c signal and at a higher attenuated input voltage to the channel. When the TRIGGER VOLTAGE control is turned toward "-", the channel triggers at a lower attenuated input voltage.

The discriminator (V303) is a two stage positive feedback amplifier. Feedback from the output stage occurs through the cathode coupling. The loop gain is slightly greater than one so that the circuit is regenerative and tends to assume one of two stable states. The output stage draws a steady current as long as the input grid remains below a certain triggering voltage. When the input exceeds this voltage the output tube is suddenly cut off. When the input voltage returns to a value slightly below the initial triggering voltage the output stage builds rapidly to its original steady current.

The difference between the level at which a positive-going voltage change triggers the circuit and the lower level at which a negative-going voltage change re-triggers it is called the hysteresis of the circuit. At the input to the comparator amplifier the hysteresis is about 0.3 volts. The hysteresis determines the input sensitivity. An attenuated input signal weaker than 0.3 volts peak-to-peak or about 0.1 volts rms will not trigger a series of pulses. This means that any noise at the attenuated input below this level will not trigger extraneous pulses, although it may affect the time at which a pulse occurs.

The primary winding of T301, differentiates the rapid current changes in the output stage to produce a positive pulse at the plate when the circuit is triggered by a positive-going voltage and a negative pulse when triggered by a negative-going voltage. The secondary of T201 produces inverted pulses -- a negative pulse when the circuit is triggered on a positive slope and a positive pulse when triggered on a negative slope.

DCU DIVIDER

(On B Modification Only)

Deck A of the FUNCTION switch (S201A) selects the signal which is divided by the DCU Divider (AY 201). During all operations other than "times ten" (x10) operations the output of the last 705AH DCU (AY 202) is coupled to the input of this divider and it functions as the last in the chain, raising the maximum count indication to 10,000,000 on the Model 7160 or to 1,000,000 on the Model 7150. During "times ten" operations the source of "start-stop" pulses is coupled to this divider through a two stage amplifier (V207), and the output of the divider becomes the "start-stop" input to the Control Circuitry. Since it produces an output pulse at every tenth input pulse, the time interval during which pulses are counted is ten times as large as it would be if the source of "start-stop" pulses drove the Control Circuitry directly. This DCU will not divide a frequency above 100 KC because its pulse resolution time is about 10 μseconds.

When the divider is part of the counting chain, Deck B of the FUNCTION switch (S201B) couples the reset pulse to pin 8 of the DCU Plug so that it resets to zero. During "times ten" operations Deck F of the FUNCTION switch connects pin 10 to -15 volts to extinguish the DCU indicator lamps and Deck D couples the reset pulse to pin 3 causing the divider to reset to nine. This is done so that the counting period will begin with the first input pulse rather than the tenth, thus eliminating an unnecessary delay.

CLOCK-PULSE GENERATOR

The Clock Pulse Generator provides

1. Pulses of a known frequency which are counted between start and stop pulses to make time measurements.
2. Start and stop pulses separated by a known time interval over which events are counted to make events-per-unit-time measurements.

The circuitry consists of an oscillator, a pulse-shaping circuit, a series of multivibrator frequency dividers, and an output trigger circuit. The shaper stage transforms the sinusoidal output of the oscillator into appropriate pulses. Each of the dividers divides the preceding frequency by ten. Decade frequencies from the shaper and the various dividers are selected by the TIME switch, shaped by the output trigger circuit (the Time Pulse Trigger) and applied to the FUNCTION switch, where they are available for start, stop or pulses to be counted.

OSCILLATOR

A crystal controlled oscillator provides a reference frequency which is divided to obtain clock pulses of various frequencies. The Model 7160 uses a 1MC oscillator and the Model 7150 uses a 100KC oscillator. In either case the oscillator consists of a two-stage amplifier with a Wheatstone bridge feedback circuit. The first stage (V401B) is a triode with an L-C tuned plate load. The triode operates as a voltage amplifier and drives the second stage V401A, a pentode which operates as a cathode follower power amplifier.

Feedback is taken from across the cathode load resistors of the pentode and fed to the inputs of a Wheatstone bridge in the cathode-grid circuit of triode. The upper arms of the bridge, consisting of R440 crystal Y401, C409 and C410, supply negative feedback to the triode grid. The lower arms consisting of RXXX and a non-linear resistor (the thermistor I401) supply positive feedback to the triode cathode. As the amplitude of the triode plate signal increases, the pentode supplies more

power to the bridge and the current through the thermistor increases raising its resistance. The higher resistance alters the voltage dividing ratio of this arm of the bridge so that less positive feedback is applied to the cathode and the amplitude of the triode plate signal is lowered. This action provides great frequency stability by limiting the amplitude of oscillation to the linear range of the circuit.

The crystal is tuned with the temperature stable capacitor C410. By adjusting the capacitor the output frequency may be shifted as much as .001%. The impedance of the crystal (Y401) varies from unit to unit. The value of RXXX has been chosen at the factory so that the voltage dividing ratio of the bridge will produce the proper amount of feedback. The triode plate circuit (L401, C403) is tuned to resonance at the oscillator frequency.

SHAPER

The shaper stage (V402) amplifies and shapes the oscillator output for use as an input to the control circuitry and the dividers. The circuit is a voltage discriminator which operates in the same way as that discussed under "Input Trigger Channels". The trigger voltage level is set by adjusting R414, L402 differentiates the rapid current changes at the output plate to produce fast positive and negative pulses. The negative transients drive the first divider through the twin diode V602. The pulse output is conducted to the TIME switch (where it may be selected to drive the Time Pulse Trigger) and directly to the FUNCTION switch where it provides pulses to be counting during the TEST operation and a start pulse for the COUNT operation.

DIVIDERS

The dividing chain consists of cascaded monostable multivibrators. Each produces one output pulse for every ten input pulses. The Model 7150 has five dividers which scale its 100KC oscillator frequency to 1 cps. The Model 7160 carries another divider preceding the last five which scales its 1MC oscillator frequency to 100KC. Although the 1MC divider (V501, V502) carries additional circuitry to fit it for high-speed operation, it operates in essentially the same way. The action is described with reference to V604. With no input the circuit is stable; the right-hand side is conducting because its grid is connectd to +120 VDC and the left-hand side is cut off. A negative transient reaching the input capacitor (C605) is coupled through R617 and R618 to each of the two plates. The negative pulse produced on the left plate is coupled by C609 to the right grid. It appears as an amplified positive pulse at the right plate, which is coupled to the left grid through C607. The left-hand side of the tube conducts, driving the left plate and the right grid even further negative. This regenerative action produces a quasi-stable stage in which the right side is cut-off and the left side is conducting. In this state the voltage on the right grid (called the "timing grid") is rising relatively slowly as the voltage at the wiper of potentiometer R656 charges the timing capacitor (C609) through R 645. At the same time negative input pulses at the right plate reach the left grid through C607 and appear as large positive pulses at the left plate. These pulses reach the timing grid through C609 and appear superimposed on the rising voltage curve there. (See Figure 11). When one of the positive pulses brings the timing grid above cut-off, the right side conducts and a reverse regenerative action returns the circuit to its original stable state. The slope of the rising grid voltage curve determines which of the successive positive pulses will rise above cut-off. The slope changes when the charging voltage at the wiper of R656 is raised or lowered. R656 is adjusted so that the ninth pulse rises above cut-off. The tenth pulse returns the circuit to the quasi-stable state.

In the interval between the ninth and tenth pulses the right side is conducting and the right

plate is negative. The negative transient produces is the useful output of the divider. It drives the next divider stage through C609 and is conduced to the TIME switch where it is available as a clock signal.

The additional circuitry associated with the 1MC divider (V501) speeds up its response. V501 is a multivibrator which operates just as V604. V502A is a cathode follower inserted between left plate of the multivibrator and timing grid. Its function is to discharge C504, the timing capacitor, within the brief 1 μsecond output pulse period so that the capacitor will pass the next positive pulse to the grid. V502B functions as a diode clamp on the left grid of the multivibrator. It prevents this grid from going so far negative during the 1 μsecond pulse output period that it will not rise above cutoff when the next positive pulse reaches it.

TIME PULSE TRIGGER

The TIME switch selects a negative output transient from one of the dividers stages and feeds it to the Time Pulse Trigger (V601). The Time Pulse Trigger is a voltage discriminator which operates in the same way as that described under "Input Trigger Channels". Output clock pulses produced at L601 are coupled to the FUNCTION switch.

POWER SUPPLY

A conventional system consisting of a transformer, two selenium bridge rectifiers and a filter network produces the +190 and -110 volt unregulated supply. Ripple on these supplies is about 10%.

The regulated +120 volt supply is obtained by dropping 190 volts through V102. The voltage drop across V102 is controlled by V101 in such a way as to maintain a constant voltage at the regulated output. A voltage dividing network (R106, R107 R113) is connected between the regulated supply and a point held 60 volts negative of ground by a

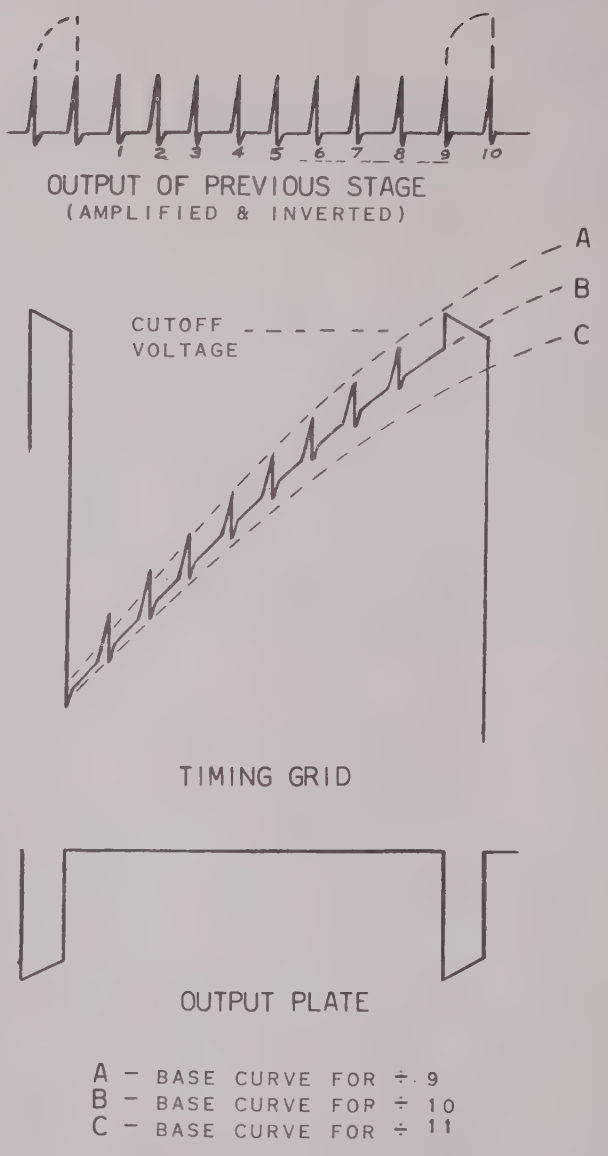
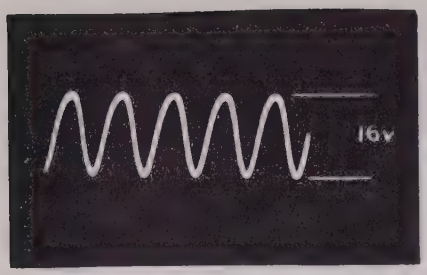


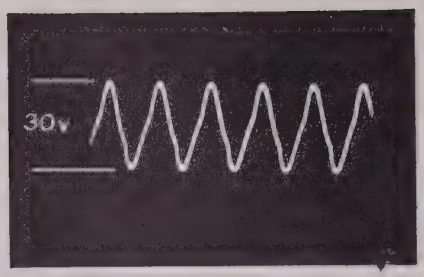
Figure 11 Divider Stage Waveforms

diode (CR103). The control grid of V101 is connected to a point on this network which is slightly below ground when the regulated supply is 120 volts. When the regulated supply varies from 120 volts, the voltage on the control grid varies proportionately and V101 delivers a signal to V102 which opposes the change.

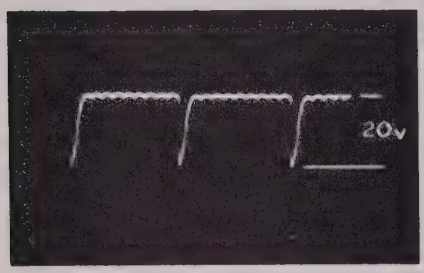
The -60 volts supply is shunt regulated by V104. Since this tube operates as a cathode follower the output voltage drawn from the cathodes remains very near the 60 volts maintained on the grids by the diode.



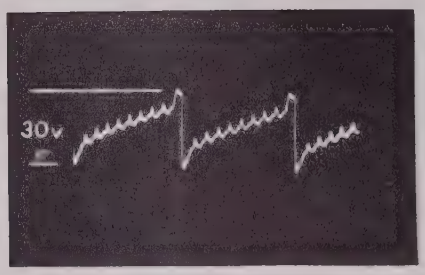
1. 1 MC Oscillator Output
V402, pin 2



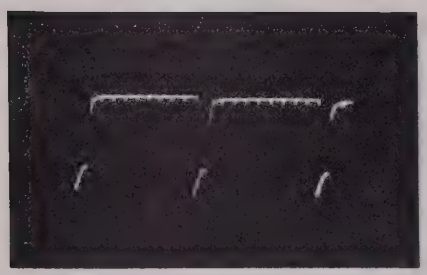
2. Shaper output, V402 , pin 1



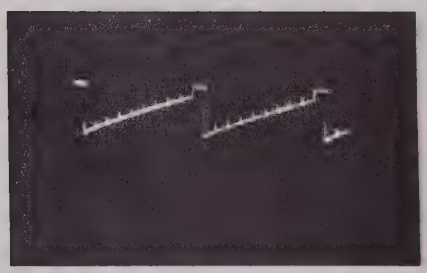
3. 1MC Divider Output Junction
of R502 and R503 (Not on Model 7150)



4. 1MC Divider timing grid.
V501 pin 2 (Not on Model 7150)

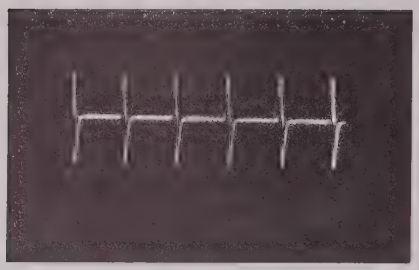


5. 100KC Divider Output
V603 , pin 6

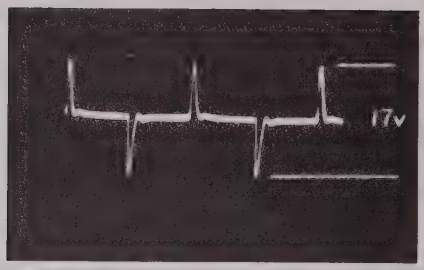


6. 100KC Divider, Timing Grid
V603, pin 7

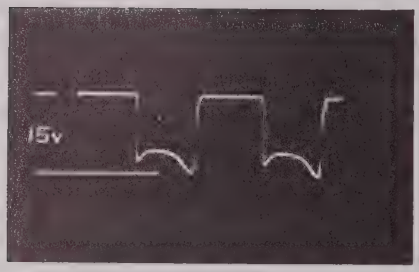
Figure 12a Typical Waveforms



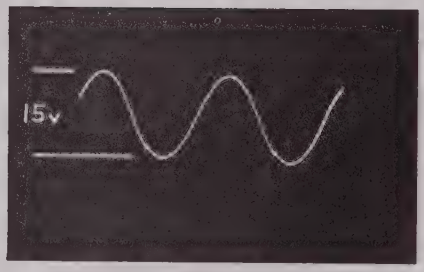
7. Time Pulse Trigger
100 KC output, V601, pin 1



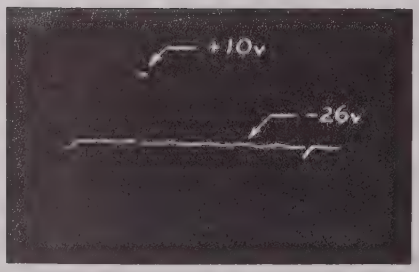
8. Discriminator output
V303, pin 1



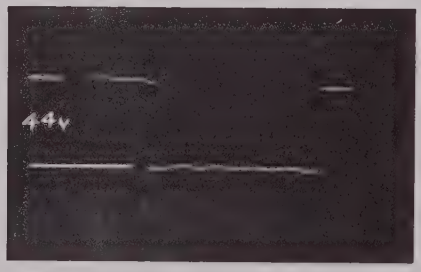
9. Discriminator amplifier plate.
100 KC signal V303, pin 6



10. Discriminator input. 100 KC
signal, V303, pin 6

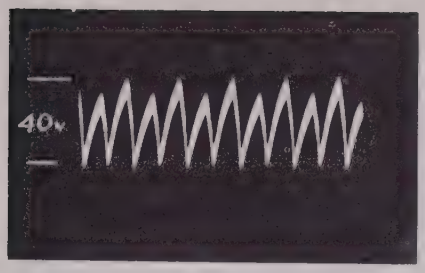


11. Gate Control Binary output.
V203, pin 1

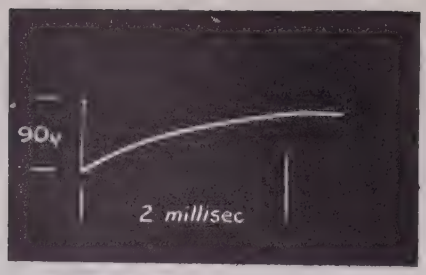


12. Start Binary output.
V202, pin 1

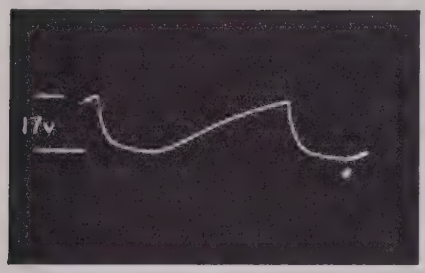
Figure 12b Typical Waveforms



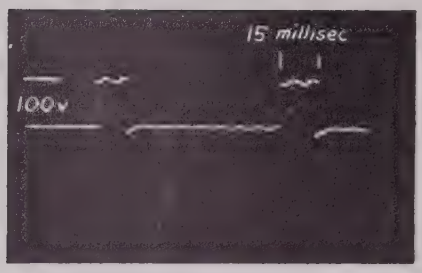
13. Signal gate output.
1 MC signal. V204, pin 5



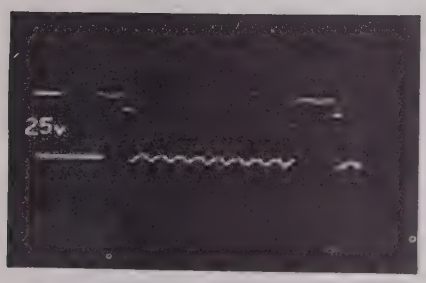
14. Reset pulse. Junction of
C215 and CR205



15. Reset Control input.
V206 pin 7

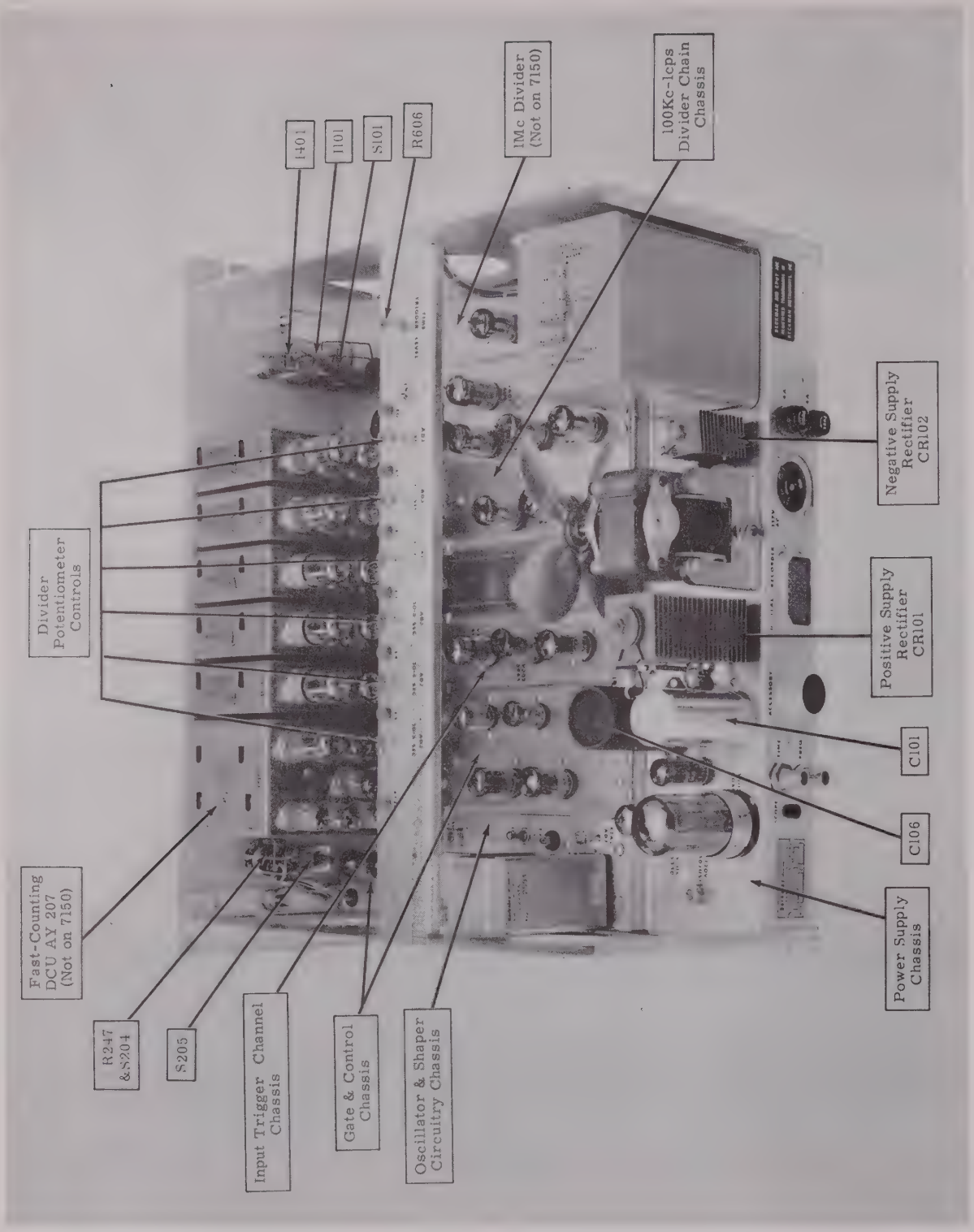


16. Reset Control output.
(minimum display time)
V206, pin 1



17. Reset Control signal to
Digital Recorder.
J202, pin 39

Figure 12c Typical Waveforms



Interior View Of Model 7160

4 Maintenance

ROUTINE ADJUSTMENTS

OSCILLATOR

The oscillator frequency can be varied by rotating the XTAL ADJust control on the top side of the counter chassis. Adjust the control until the oscillator signal which appears at the FREQuency jack comes to zero beat with a WWV signal or some other highly accurate frequency standard.

The oscillator is adjusted to maximum stability by a slug-tuned inductor (L401) in the plate circuit of the oscillator triode (V401B). Do not use this control to vary frequency. L401 is located on the under side of the chassis near the SHAPER LEVEL potentiometer. Normally, an adjustment is required only when a tube or some other component has been changed. Adjust the slug very carefully for a maximum signal at pin 6 of V401A.

A third oscillator adjustment should be made whenever the crystal is replaced. Observe the signal at pin 6 of V401A with an oscilloscope Vary the resistance of RXXX by adding resistors in series or parallel until the positive peak of the sinusoidal waveform is flattened just enough to be noticeable.

SHAPER

The shaper stage in the clock-pulse generator is a voltage discriminator similar to those in the Input Trigger Channels. The SHAPER LEVEL control, located on the top side of the counter chassis, sets the trigger voltage at the input to this circuit. To adjust, set the FUNCTION switch at TEST. Find the limits of the range of adjustment in which the instrument continues to count. Set the control at the center of this range.

DIVIDERS

If the instrument fails to indicate correctly with the FUNCTION switch at TEST, one or more dividers may be out of adjustment. Some Model 7160 instruments may read "9" with the TIME switch at 10^{-5} and "99" with the switch at 10^{-4} These readings are correct provided the unit reads "999,999" or "1,000,000" at the 1 second position. Dividers should be adjusted using the potentiometer controls located under the cabinet lid and labeled "ADJ 1 SEC; ADJ 10^{-1} SEC;" etc. To adjust, place the FUNCTION switch at TEST, then follow the procedure for the model you are servicing.

Adjustment procedure for Model 7150.

1. Turn TIME switch to 10^{-4} and measure the d-c voltage between test point E4 and ground. Rotate the ADJ 10^{-4} SEC control to the extremes of the range in which reading of 10 appears on the DCU's, noting the test point voltage at each extreme. Then adjust the control until the test point voltage is midway between the extreme values.
2. Turn TIME switch to 10^{-3}. Measure voltage at E3. Rotate ADJ 10^{-3} SEC control to extremes of range which reads "100", noting test points voltages at extremes. Adjust control until voltage is halfway between extremes.
3. With TIME switch at 10^{-2}, set ADJ 10^{-2} SEC control similarly but to center of voltage range in which either 1000 or 999 appears.
4. Adjust the remaining controls in order to the center of the 10,000 or 9,999 range, and the 100,000 or 99,999 range.

Adjustment procedure for Model 7160.

1. Turn TIME switch to 10^{-5} and measure the d-c voltage between test point E5 and ground. Rotate the ADJ 10^{-5} SEC control to the extremes of the range in which a reading of 10 appears on the DCU's noting the test point voltage at each extreme. Then adjust the control until the test point voltage is midway between the extreme values.

2. With TIME switch at 10^{-4}, rotate the ADJ 10^{-4} SEC control to the center of the range in which either 99 or 100 appears.

3. With TIME switch at 10^{-3}, rotate the ADJ 10^{-3} SEC control to the center of the range in which 999 or 1000 appears. (See step 4.)

4. If neither of these readings can be obtained, return the TIME switch to 10^{-5} and re-adjust the ADJ 10^{-5} SEC control to the center of the range in which 9 (rather than 10) appears. Then, repeat steps 2 and 3 above.

5. With TIME switch at 10^{-3}, adjust all three controls (10^{-5}, 10^{-4} & 10^{-3}) to the center of the range in which either 999 or 1000 appears.

6. Adjust the remaining controls in order to the center of the 10,000 or 9,999 range, the 100,000 or 99,999 range and the 1,000,000 or 999,999 range.

The adjustment of each divider affects the adjustment of the others slightly. Therefore, after the initial adjustment outlined above, a final adjustment should be made. With the FUNCTION switch at TEST, set the TIME switch to 10^{-1}.

On the Model 7160, a reading of 100,000 or 99,999 will appear. Adjust in turn ADJ 10^{-5} SEC thru ADJ 10^{-1} SEC to the center of the corresponding test point voltage range within which either of these readings appears. Then, set the TIME switch at 1 and rotate ADJ 1 SEC to the center of the voltage range at E0 within which either 1,000,000 or 999,999 appears.

On the Model 7150, a reading of 10,000 or 9,999 will appear. Adjust in turn ADJ 10^{-4} SEC thru ADJ 10^{-1} SEC to the center of the corresponding test point voltage range within which either of these readings appears. Then move the TIME switch to 1 and rotate ADJ 1 SEC to the center of the voltage range at E0 within which either 100,000 or 99,999 appears.

REGULATED 120 VOLT SUPPLY

Measure the supply voltage at the test point labeled "+120V" with an accurate voltmeter. Adjust +120V ADJUST, located on the top side of the counter chassis, for a reading of 120 volts.

TIME PULSE TRIGGER

The Time Pulse Trigger (V601) is a Schmitt trigger circuit. The TIME TRIGGER LEVEL control varies the instantaneous voltage at which an input signal triggers the circuit from one state to another. Whenever the tube is replaced, adjust the control until, with no input signal, the potential on the input grid (Pin 2) is -1 volts with respect to the cathode (pin 7). Check TEST operation under two conditions: (1) line power reduced to 105 volts and TIME switch at 1 second (2) normal line voltage and TIME switch at 10^{-6} seconds. An incorrect adjustment will cause either a reading of 100,000 rather than 1,000,000 at the 1 second position or no reading instead of "1" on the 10^{-6} seconds position. If necessary, re-adjust the control until correct readings are obtained under both conditions.

ATTENUATOR ADJUSTMENTS

Two ceramic trimmer capacitors on each attenuator assembly must be adjusted properly to prevent the attenuator from distorting the input signal. When the counter chassis is upside down and the attenuator shafts are pointing at the viewer, the capacitor on the right side of each attenuator is C303 and that on the left C302. To adjust, apply a 500 cps square wave signal at one of the counter INPUT jacks. Observe the corresponding amplifier output at Pin 1 of V302 with a 100KC band-width oscilloscope. Turn the attenuator to 10 on the AC side. Adjust the input signal to about 1 volt peak-to-peak. Adjust the TRIGGER VOLTAGE control to any position in which the channel triggers. Adjust C303 for a square wave output. Then, turn the attenuation control to 100 on the AC side and adjust the input signal to about 10 volts peak-to-peak. Adjust C302 for a square wave output.

The following test equipment is necessary to service the instrument effectively:

1. An oscilloscope, sensitivity 1/4 volt, bandwidth 5 MC, preferably direct coupled.
2. A signal generator, frequency range 100 cps to 1MC, output at least 100 mv rms.
3. A vacuum tube voltmeter.

When the instrument fails to perform properly, first make sure that it is being operated correctly. Some common errors in operation are:

1. TRIGGER VOLTAGE control positioned incorrectly.
2. ATTENUATION control set incorrectly.
   (a) Wrong choice of AC or DC coupling.
   (b) Attenuated signal too strong or too weak.
3. SLOPE switches set incorrectly. (see "PERFORMING SPECIFIC OPERATIONS" for correct setting for each operation.)
4. Input signal coupled to wrong jack.
5. Wrong TIME switch setting
   (a) Unit of time measurement too large to measure a brief period under PERIOD operation.
   (b) Time interval too short to measure a low frequency under events-per-unit-time operation.
6. Too much noise on input signal.

When it is certain the instrument is functioning improperly, first check the power supply voltages to see that they lie within the limits listed below.

Supply	Limits of average level	Acceptable ripple
Unreg. pos.	+190v ±10%	15v peak-to-peak
Unreg. neg.	-110v ±10%	5v peak-to-peak
Reg. Pos.	+120v to accuracy of adjustment	0.1v peak-to-peak
Reg. Neg.	-55v to -65v	0.5v peak-to-peak

If the supply voltages are adequate, the next step is to trace the failure to one of the major components. This can be done by observing the start, stop and count pulses at Decks C, E & G respectively of the FUNCTION switch. If the signals at these points approximate the proper output waveforms of the pulse sources, the trouble lies in the Gate and Control Circuitry or the indicating DCU's. Refer to the schematic diagram, Figure 13, to determine the source of pulses when the FUNCTION switch is in a particular position. If a deficient pulse is found the trouble lies in that pulse source.

When the trouble has been traced to one of the major components consult the Circuit Description section of this manual and the waveforms of Figure 12 for guidance in locating the specific fault. The Input Trigger Channels may be conveniently checked by observing whether or not a pulse is produced as the TRIGGER VOLTAGE control is rotated from one extreme to the other and back.

Tubes, chokes, germanium diodes and pulse transformers are the most common sources of trouble. A transconductance tube tester will not always detect a faulty tube and, conversely, the tester may reject a tube which is functioning properly. Although the circuits are designed for wide tube variation, avoid swapping tubes or wholesale replacement. An aged tube is generally more reliable than a new tube, because catastropic failure usually occurs early in the life of a tube if at all. An aged tube undergoes only a gradual loss of transconductance, emission, etc.

The Sylvania 6U8 tube is recommended for use in trigger circuits V303, V402 and V601.

6 Modifications

NOTE: Modified instruments are identified by a letter or letters after the model number. For example, the Model 7150 D is a standard Model 7150 Eput Meter modified as described below under "Modification D". An instrument may be modified in more ways than one; for instance, the Model 7150DK is a Model 7150 changed in accordance with both "Modification D" and "Modification K". The entire instruction manual except this section on modifications describes a standard instrument.

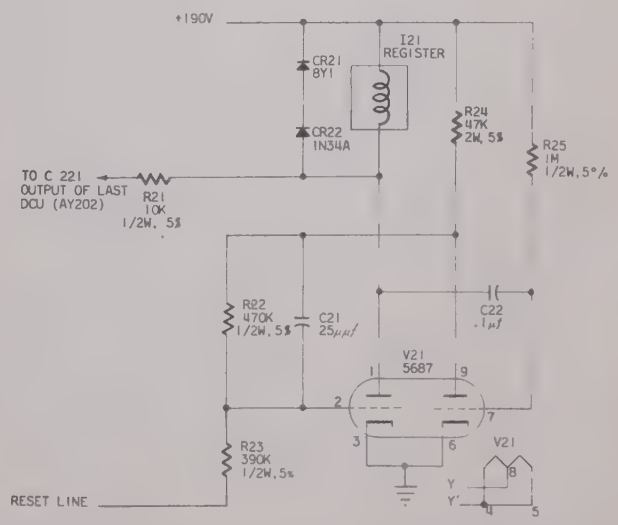
MODIFICATION B

This consists of adding a dual-purpose decimal counting unit to 7000 Series instruments which do not normally contain such a unit. Depending on the position of the FUNCTION switch, this DCU either extends the count capacity by a factor of 10 or divides the frequency of the pulses which start and stop counting by 10. This modification described in greater detail under "DCU Divider" in the "Circuit Description" section of this manual.

MODIFICATION C

This consists of the addition of a mechanical register which will extend the counting capacity of any 7000-series instrument by a factor of 10^3. Instead of using the electronic signal which resets the DCU's, the register is reset by a small lever on the front panel directly below the mechanical count-indicating dials.

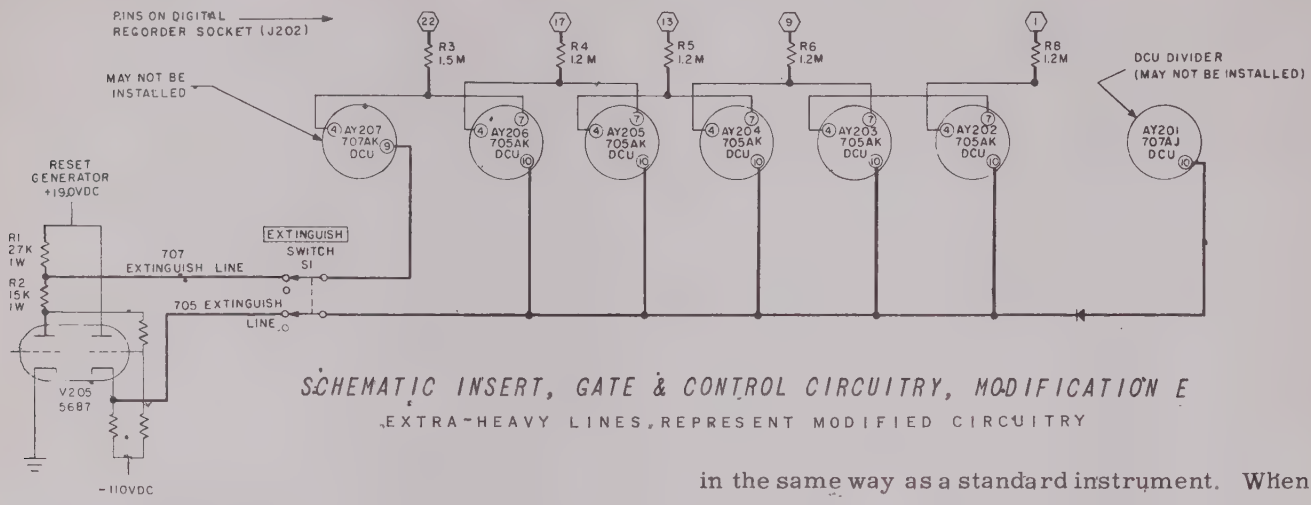
On instruments with "X10" positions on the FUNCTION switch, the indicating panel of the DCU Divider (AY201) is not exposed to view when the C modification is made. The digit normally displayed by AY201 is shown at the right-hand digit of the register dial. AY202, the last exposed DCU next to the register, drives V21, a one-shot multivibrator. Each time this is activated a count is recorded on the mechanical register, the coil of which is the multivibrator plate load. When AY202 resets, a counting pulse may appear in the output. To counteract this, the reset line is connected to control-grid pin 2 of V21, so that whenever a reset pulse causes a count from AY202 to appear on the plate pin 1 of V21, the reset pulse also appears at the grid. The two pulses, opposite in polarity, counteract each other so that no count is recorded at the register.



SCHEMATIC INSERT, GATE & CONTROL CIRCUITRY, MODIFICATION C

This consists of substituting a 100Kcs heated crystal in the oscillator of the clock-pulse generator in place of a 100Kcs unheated crystal. This modification is applicable only to 7000 Series instruments which normally contain an unheated crystal (for example, Models 7150 and 7250). The heated crystal has a stability of 1 part in 10^6 per day as compared with a stability of 1 part in 10^5 per day for the unheated crystal.

MODIFICATION E



SCHEMATIC INSERT, GATE & CONTROL CIRCUITRY, MODIFICATION E

EXTRA-HEAVY LINES REPRESENT MODIFIED CIRCUITRY

This consists of replacing the standard decimal counting units with DCU's whose indicating bulbs can be extinguished automatically while the instrument is actively counting. With automatic extinguishing, the indicating bulbs light only at the end of each counting period to display the result.

The accompaning schematic insert shows how the circuitry of the standard instrument is modified. The voltage which extinguishes the DCU bulbs is supplied by the reset generator while it functions as usual in the standard automatic operating cycle. Both "extinguish lines" leading from the reset generator are at a relatively negative voltage at all times except during the display period. The relatively-negative voltage applied to the DCU's prevents the neon bulbs from lighting. The relatively-positive voltage on the "extinguish lines" during the display period permits the bulbs to light.

The EXTINGUISH toggle switch is located on top of the counter chassis. It may be exposed by lifting the top lid of the instrument. When this switch is closed the indicating bulbs are automatically extinguished as described above. When the switch is open the counter operates in the same way as a standard instrument. When counting is controlled manually (that is, by moving the FUNCTION switch from OFF to COUNT and back again) the EXTINGUISH switch should be open. Under manual control no automatic display period occurs, so the reset generator always supplies a voltage which would extinguish the indicating neons if connected to the DCU's.

All 705AH DCU's in the standard instrument are replaced by 705AK DCU's. Pin 10 of the DCU socket is connected to an "extinguish line" instead of to a pin in the DIGITAL RECORDER socket. The DIGITAL RECORDER pin which ordinarily connects to pin 10 is connected instead to pin 4 through a 1.2 megohm resistor.

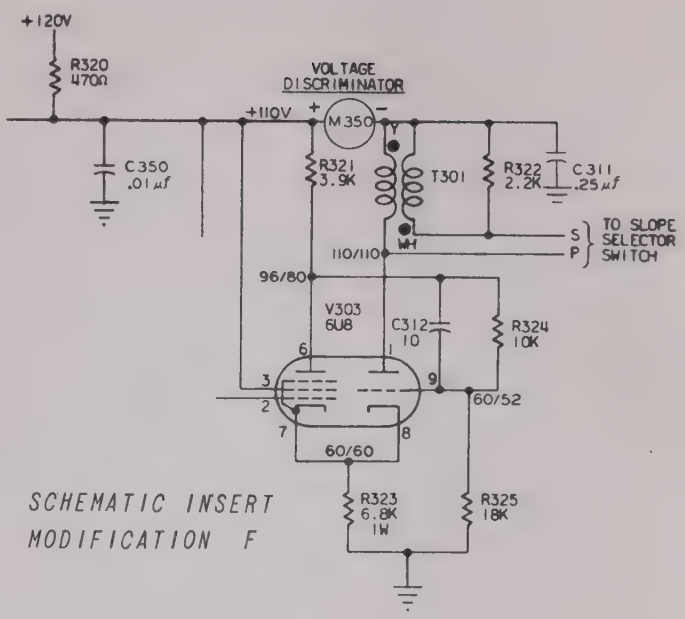
If the standard instrument has a maximum counting rate of 1 Mcs, it contains a 707AH DCU. This DCU is replaced by a 707AK DCU. An "extinguish line" is connected to pin 9 of the DCU socket, and the DIGITAL RECORDER pin which is ordinarily connected to pin 9 is connected instead to pin 4 through a 1.5 megohm resistor.

If the standard instrument is equipped with a DCU used as both a counter and a frequency divider (Model 705AJ), an "extinguish line" is connected to pin 10 of its socket.

MODIFICATION F

This consists of making modifications B, D and R plus adding a TRIGGER STATE meter to the E/UT input channel. The meter aids in adjusting the TRIGGER VOLTAGE control. The operator should adjust this control until the meter pointer stays in the center green region.

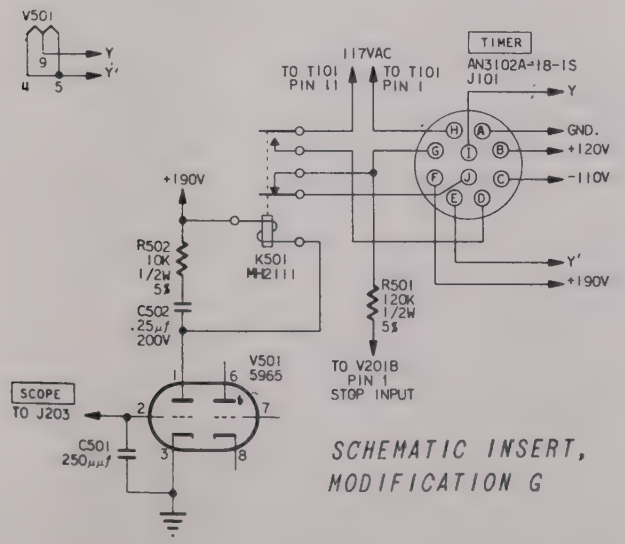
The TRIGGER STATE meter actually indicates the plate current flowing in the output triode of the voltage discriminator in the E/UT channel. This stage has two stable states: cut-off and conducting heavily. When the triode is cut-off, the meter indicates zero; when it is conducting, the meter is deflected to approximately full scale. The triode is triggered from one state to the other and back again by each input signal cycle. If the input frequency is above 10 cps the inertia of the meter will cause it to indicate the average plate current. A meter reading in the center green region indicates that the triode is cut-off half the time and conducting the other half. Under these conditions the channel produces the most reliable pulse output to be counted on the DCU's.



SCHEMATIC INSERT
MODIFICATION F

MODIFICATION G

This modification provides connections so that an external timer can be used to extend the sampling time of the counter. The labeling of J101 is changed from "ACCESSORY" to "TIMER". This socket provides 117 volt ac for operating the timer motor and it provides ground and Control Binary stop-input pin connections to the time-delay switch in the timer.



SCHEMATIC INSERT,
MODIFICATION G

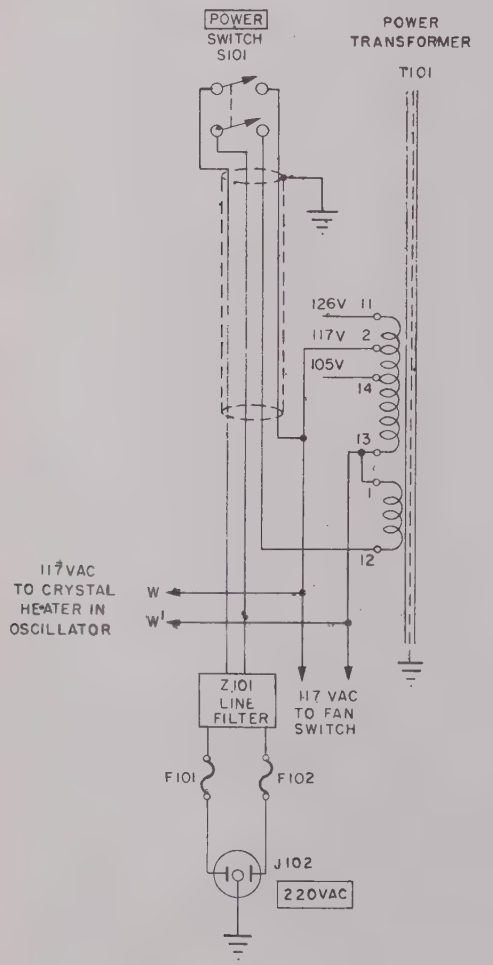
The G Modification functions with a timer in this manner. The timer dial is set to indicate a certain interval of time. A switch in the timer grounds the stop-input pin (pin 1, V201 B) of the Control Binary (V203), so that once the counter starts counting it will not stop until the stop-input pin is un-grounded. The Relay Control tube (V501) conducts and energizes relay K501 when the Signal Gate (V204) "opens". (V501 is caused to start and stop conducting by the same signals that "open" and "close" the Signal Gate--that is, the output of the Control Binary.) When the relay energizes, it closes the contacts which supply 117 volts ac to energize the timer motor. After the pre-determined time interval, the time switch opens, and the Control Binary stop-input pin is removed from ground. The next clock pulse causes the Control Binary to "close" the Signal Gate and cut off the Relay Control tube (V501). K501 is de-energized, its contacts open and remove the power from the timer motor. At this point, the timer resets.

When the external timer is not used, remove the cable from the TIMER socket and the counter will operate normally.

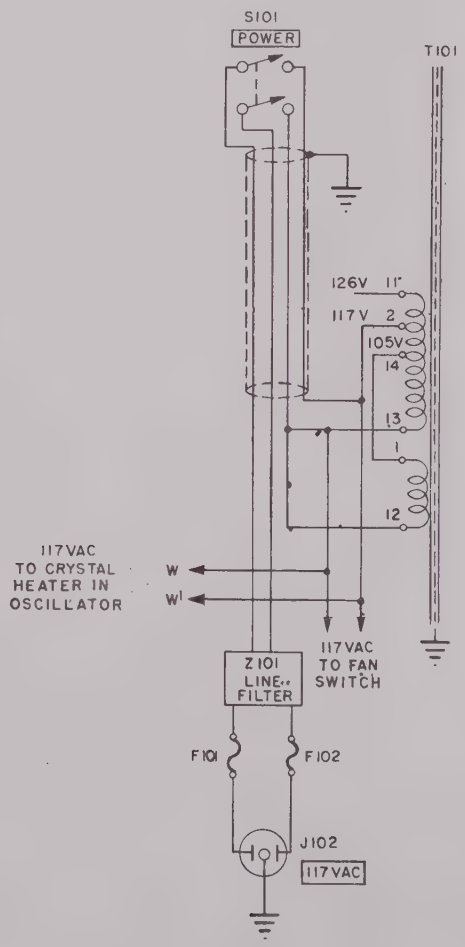
MODIFICATION H

This consists of modifying the instrument so it can be operated off a 220-volt line. The standard 117-volt power transformer is replaced by transformer having two primary windings, a 117-volt winding and a 105-volt winding. As shipped, these windings are connected in series so that when the instrument is connected to a 220-volt line, the proper voltage appears across each winding. The schematic insert below shows the modified circuitry. The line fuses (F101 & F102) in the standard counter have been replaced by fuses of one-half the standard current rating. Note that the crystal oven in the oscillator will no longer begin heating as soon as the instrument is plugged in, but will heat only when the POWER switch is on.

An instrument modified to operate on 220 volts can be reconverted to operate on 117 volts by changing the connections to the primary of the power transformer (T101) and replacing the line fuses. To do this break the connection between transformer terminals 1 and 13 and connect terminal 1 to terminal 14 and terminal 13 to terminal 12. Replace line fuses F101 and F102 with fuses of twice the current rating of those installed. The resulting circuitry is shown in the schematic insert below. Note that the 117-volt winding is connected across the line and that the 105-volt winding is connected in parallel with part of the 117-volt winding.



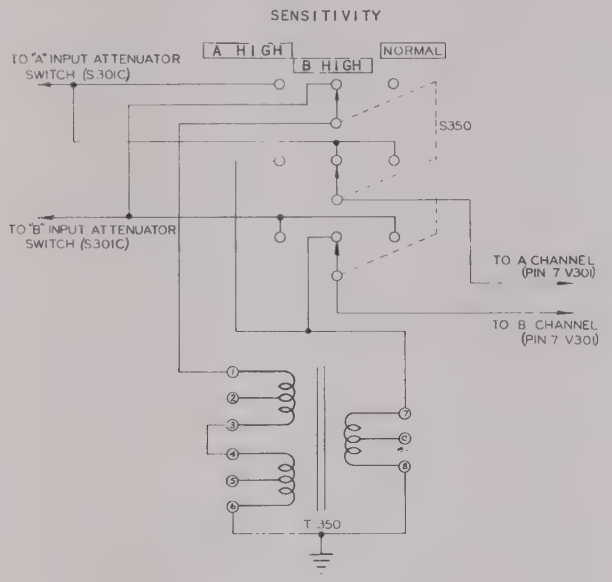
SCHEMATIC INSERT, POWER SUPPLY, MODIFICATION H



SCHEMATIC INSERT, POWER SUPPLY, MODIFICATION H RECONVERTED TO OPERATE ON 117 VOLTS AC.

MODIFICATION K

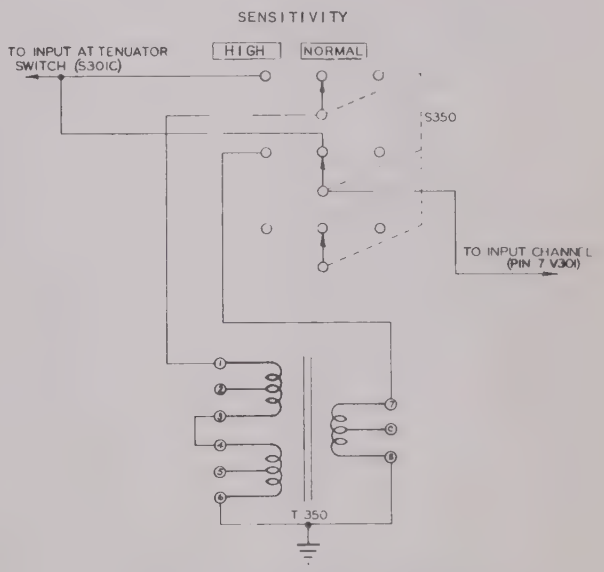
The purpose of this modification is to increase the input sensitivity of the counter from 100mv rms to 5mv rms. This is done by adding a step-up transformer in the input circuit. The operator may insert and remove the transformer by positioning a front-panel sensitivity switch.



WIRING FOR TWO INPUT CHANNELS

If the modified instrument has two input channels, the front-panel switch will have three positions marked "NORMAL", "A HIGH" and "B HIGH". At NORMAL the transformer is not connected to either input channel, and the instrument functions just as though it had not been modified. At A HIGH the step-up transformer is connected between the attenuator and the input grid of the A channel. At B HIGH the transformer is inserted between the B attenuator and the input grid of that channel. If the modified instrument contains only one input channel the front-panel switch has only two positions; one marked "NORmal", the other marked "HIGH".

Do not insert the transformer in an input channel unless the input signal is below the normal sensitivity of the counter. With the transformer connected in a channel the ATTENUATION control should be at DC-1. The input impedance is then the impedance of the transformer primary. This winding has 50 ohms resistance and an inductance of 8.3h when coupled to a 10mv signal at 60 cps. The sensitivity is 5mv rms from 5 cps to 1000 cps.



WIRING FOR ONE INPUT CHANNEL

MODIFICATION R

This consists of simply removing the cabinet from the chassis and the attached front panel and adding dust covers-top and bottom. When this is done the counter may be mounted in a standard relay rack.

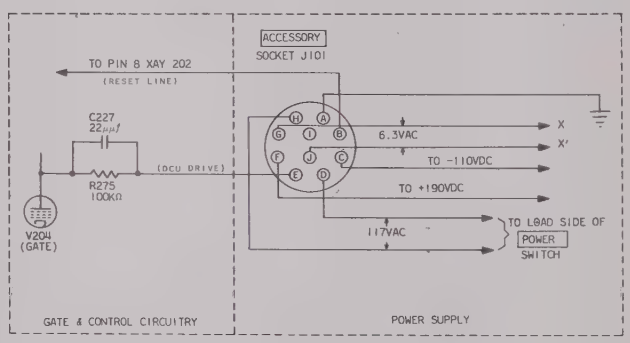
MODIFICATION T

This consists of the V modification plus a half-second clock-pulse interval in place of the usual 1-second interval. The last stage of the Frequency Divider Chain is modified from a divide-by-ten to a divide-by-five stage. This is done by changing the value of timing capacitor C617 from 0.47μfd to 0.25μfd. The extreme clockwise position of the TIME-SECONDS switch is also changed to read ".5". When using an instrument with this modification keep in mind that the maximum sampling time available is 0.5 seconds, not 1.0 seconds.

MODIFICATION V

The V modification provides DCU Drive and Reset signals as well as power at the ACCESSORY socket (J101) for operating a remote indicator consisting of several cascaded DCU's. The DCU drive signal is taken from the plate of the Signal Gate (V204). The signal is passed through a network which reduces its amplitude and its output impedance before it reaches the ACCESSORY socket. The Reset signal is taken directly from the reset line (pin 8 of the DCU's). In addition, B+ and B- voltages are available at J101, as well as 117 volts ac to power a fan and a filament transformer.

The DCU's may be removed from the counting instrument and placed in the remote indicator. If this is done there will no longer be a signal at J202, the DIGITAL RECORDER socket, for operating an accessory recorder. With the remote indicator in use, operate the counting instrument in the usual manner. When the remote indicator is not used, disconnect the indicator cable from the ACCESSORY socket.



SCHEMATIC INSERT, MODIFICATION V

Supplementary Service Notes, SSN7000

Introduction. These notes cover recommended methods of servicing any instrument in the BECKMAN/Berkeley 7000 Series. This includes Models 7050, 7060, 7150, 7160, 7250, 7360, and the counter portion of Model 5571. Some of these instruments do not contain all the major components treated below (for example, Models 7250 and 7260 do not contain a frequency dividing chain); therefore, ignore inapplicable references.

Training and Experience Required. Any person who knows basic electronics and has used a scope and vacuum-tube voltmeter should not hesitate to undertake the repair of a Beckman counting instrument. Short of actual factory training, reading the instruction manual is the best way to familiarize oneself with the instrument. A detailed study of the schematics will yield additional knowledge, and, studied along with an actual instrument removed from the cabinet, will familiarize one with the layout of the components. Strive to keep the block diagram in mind, the details will fall in place as experience is gained.

Checking Instrument Upon Receipt. Occasionally, upon receipt by a customer, an instrument will fail to operate properly. This may be due to rough handling or vibration that has taken place in shipment. The cause of the trouble most often will be a loose tube or perhaps some other loose plug-in component, such as a DCU or a crystal. In some cases a time base divider may require re-alignment, but rarely is more than one divider out of adjustment. Refer to the manual for proper alignment procedure, and be sure to use an auto-transformer on the 117-volt input line in order to test the alignment over any expected line swing within the specified variation of ±10 per cent. Check to see that the switch on the cooling fan is turned on. At the same time make sure the INT-EXT switch on the oscillator sub-chassis is in the INT position. If the pilot light fails to come on when the POWER switch is thrown, there is probably a loose or broken line fuse. These fuses are located on the rear of the chassis.

Routine Care of Instrument. As time goes on, dust and grit may accumulate inside the chassis. This should be removed with an air hose and brush to prevent deterioration of components. Remove the tubes and clean the tops of the sockets with a rag. Make sure that the cooling fan rotates at normal speed.

HOW TO TRACE A FAULT TO A MAJOR COMPONENT

Examining Operating Characteristics. Refer to the schematic diagram of the gate and control circuitry. You will notice that the complete instrument, excluding the power supply, is shown on this page either in detailed schematic form or block diagram. It is your best overall look at the instrument and with reference to this diagram you can trace the signal and pulse paths through the function switch to their destinations. Understanding this diagram is the key to the isolation of troubles in the entire instrument. Notice that the input trigger channels, the oscillator and the frequency dividing chain all feed pulses to the FUNCTION switch, but that at some positions of the FUNCTION switch not all the pulse sources are coupled to succeeding circuits. Since some major components are not used while performing certain operations, a fault may often be localized by observing which functions fail. For example, no pulses from an input trigger channel are used during the TEST operation; therefore, one may reasonably suppose an input channel is at fault if the instrument operates all right at TEST, but does not operate with an input signal. To take another example, the frequency dividing chain has no part in the COUNT operation, so if the instrument performs this function successfully when other functions fail, one may suspect the dividing chain.

Signal Substitution Using Another 7000 Series Instrument. Another 7000 Series instrument in good operating condition is a great help in localizing trouble. Make up a couple of patchcords, three or four feet in length, and having the BNC type connectors on both ends. These will serve to conduct pulses from one unit to another. On the rear lip of the chassis you will find two connectors, one labeled TIME and the other FREQ. The clock pulses from the frequency dividers are available at the TIME jack, and the oscillator frequency is present at the FREQ jack.

If you suspect incorrectly timed clock pulses in a faulty instrument, their accuracy can be checked by introducing the clock pulses from a good instrument into the B channel of the defective instrument and obtaining a readout in the PER function. Make this test with several combinations of the TIME-SECONDS switch on both instruments. Have both SLOPE switches at the same polarity. Be sure that the oscillator of the good instrument has been carefully set to the correct frequency before attempting this type of test.

Another test is to patch the oscillator output from the good unit into the FREQ jack of the faulty one and throw the INT-EXT switch, located on the oscillator sub-chassis, to the EXT position, thus bypassing the oscillator of the defective instrument. Don't overlook the possibility of counting the clock pulses from a good instrument as a check on the accuracy of the E/UT function of a suspected instrument.

Observing Pulses at the FUNCTION Switch. The FUNCTION switch consists of four wafers. With one exception, there are contacts on both sides of each wafer. The contacts on each side make up one section, and each section is identified on the schematic diagram of the gate and control circuitry by a letter from A to G. Section A is the rear side of the wafer nearest the front panel (the forward side of this wafer is not used). The forward side of the second wafer is section B; the rear side, section C, and so on. A scope probe may be conveniently placed on the wiper contacts of sections C, E and G in order to observe "start", "stop" and "count" pulses respectively. These pulses originate in one or another of the major components depending upon the position of the FUNCTION switch. By rotating the switch to various positions, one may observe the output of an input channel, the oscillator-shaper, and (in conjunction with the TIME switch) the output of any frequency divider.

INPUT TRIGGER CHANNELS

Referring to the schematic, notice that the internal test signal does not pass through an input trigger channel, so, given a correct reading at TEST, it is a good bet that the trouble lies here. There are only three tubes in an input channel and the entire channel is contained on one sub-chassis. Thus troubleshooting is confined to a small amplifier-shaper section of the circuitry.

No one can state as a general rule where the trouble will be found in an input channel. The most likely cause of trouble is a defective tube and substitution should be tried. Then, of course, find out if the correct supply voltages are present. It is always wise to check supply voltages before doing any trouble-shooting, but remember if we found a correct TEST reading, we can assume that the supply

voltages are correct for most of the circuitry. Ordinary signal tracing, using the scope, may be employed on an input channel and typical voltages listed on the diagram may be verified with a vacuum-tube voltmeter. Don't overlook comparison of waveforms with those of a similar instrument that you may have in your possession, but remember that the attenuator and trigger voltage controls should be in identical positions on both instruments. Turn off the power to the faulty instrument and take resistance measurements, perhaps the defective component will show up by this method. At any rate one of the above methods should yield results and the time required for the repair will depend on the skill of the technician and his familiarity with the instrument.

OSCILLATOR-SHAPER

The oscillator is the heartbeat of a 7000 series instrument; without it, operation ceases, except for the A/B function which is independent of the oscillator. Therefore, one of the first things to investigate, after noting a complete failure to count in the TEST position, is the oscillator.

Look at the oscillator sub-chassis to be sure that the INT-EXT switch has not been accidentally thrown to the EXT position. At the same time look at the small feedback lamp projecting up through the rubber grommet and notice whether it has been broken. Put the scope probe on pin 2 of V402, (or on the FREQ jack on the rear of the instrument): the oscillator output waveform should appear, a distorted sine wave in the range of 10 to 16 volts peak-to-peak. A value of about 12 volts is normal, but the instruments will operate correctly over at least the range noted above. If this waveform is not present, adjust C410, marked "XTAL ADJ" on the chassis. (Upon completion of the repair, don't forget to reset this control so that the oscillator frequency will be precise.) If a spare crystal is available it should be tried as a substitute but with a new crystal the value of RXXX may need to be changed as suggested in the manual. A new feedback lamp, I402, may be tried and other components and wiring can be checked with an ohmeter.

Located on the same sub-chassis as the oscillator is the shaper circuitry. This section amplifies and shapes the signal generated by the oscillator. If the proper oscillator signal was found to be present when checked with a scope at pin 2 of V402, the oscillator is not at fault and trouble may be found in the shaper. Place the scope probe on pin 1 of V402; a waveform should appear, with a peak-to-peak value of from 12 to 20 volts. The appearance of this waveform will differ in the 100kc and 1mc models, and will also depend on the setting of the SHAPER LEVEL control, R414, located in the pin 2 grid circuit of V402.

After repairing the trouble be sure that the SHAPER LEVEL control is reset properly as described in the manual, but, before doing this, rotate it back and forth, noting whether operation is restored with the FUNCTION switch at TEST. You will find that there is a range of settings within which the instrument will perform correctly, but a setting well to the side of this range may cause entire lack of amplification through the shaper tube. Other points to check are the B supply voltage, the tube and the small choke coil, L402. Other components may be checked in the usual manner. Most component values in the oscillator-shaper circuit are not critical.

TIME BASE DIVIDERS

Be sure to make use of the circuit description and waveforms published in the instruction manual when shooting troubles in the dividers. The amplitudes listed on the waveform photographs are approximate: there is appreciable variation among instruments. It is advisable to become familiar with the adjustment of the dividers before trouble occurs. Practice on an instrument that is known to be in good operation. Put the unit in the TEST function and take note of the readings obtained as the first divider is misadjusted, then the second, the third and so on. An actual trouble will probably occur in a single divider only, so the complication of more than one divider being out of adjustment is rare.

Make certain that the supply voltage of +120 volts is present and well-regulated. Make sure that the input pulses from the oscillator-shaper are entering the divider chain. Use the TIME-SECONDS switch and the readout on the DCU's to pin down the defective stage. Check division ratios with a scope at the points suggested in the manual. A slight adjustment of one divider may bring a unit back to normal, or perhaps the replacement of one tube may have the same result. Do not overlook the possibility that the TIME TRIGGER LEVEL control (R606) is set incorrectly. Aged tubes should be used as replacements in the divider chain in order that the original adjustment will hold for several months or more. Replacements for the 6U8 (V601) should be Sylvania brand for best performance. The adjustment procedure for the dividers and the TIME TRIGGER LEVEL control is well covered in the instruction manual; no further mention will be made here.

The voltages shown in the table on page 6 will be of real help in servicing the dividers. Notice that all the dividers, except V501 (contained in Models 7160 and 7360 only), are identical, so voltages and resistances in one stage may be compared with those in another. A convenient point to monitor the clock pulses is at the TIME jack, located on the rear lip of the chassis.

GATE AND CONTROL CIRCUITRY

Learning How the Circuits Operate. No one can hope to be successful in troubleshooting the control circuitry unless he understands the operating cycle. First, study the circuit description and the cyclic timing diagrams reproduced in the manual. Second, if possible, study the circuitry in a well-functioning instrument while it resets in each of its three stable states: "ready time", "counting time" and "display time". (The fourth state of the operating cycle, the "inhibit start time", is a transient condition lasting only a few milliseconds.) Use the following procedure:

(a) Rotate the DISPLAY control clockwise until a switch clicks. This prevents the instrument from resetting automatically.

(b) Place the FUNCTION switch at some position at which an input trigger channel supplies "start" and "stop" pulses, but do not couple an input signal to the channel.

(c) Press the RESET button. After a brief "inhibit start" period, the circuitry should switch to the "ready time" state. This state may then be studied deliberately with a VTVM.

(d) Introduce a "start" pulse by rotating the trigger voltage control on the input channel back and forth. The circuitry should then assume the "counting time" state.

(e) Introduce a "stop" pulse by moving the trigger voltage control back and forth again. This should place the circuitry in the "display time" state.

Troubleshooting. The control circuitry is the most difficult part of the instrument to service; therefore, be sure it is receiving adequate input signals ("start", "stop" and "count" pulses) before beginning to search for trouble. The following troubleshooting procedure is recommended.

Step 1. Observe signal at control grid of gate tube (V204, pin 1). Pulses to be counted should appear here. If not the DCU's will not count even though the control circuitry is functioning perfectly.

Step 2. Observe the d-c voltage change at the gating grid (V204, pin 7) while the control circuitry is receiving start and stop pulses separated by one second or more and is adjusted to reset automatically. If the d-c voltage switches back and forth from -15v or more negative to ground level or more positive, the control circuitry is operating all right. In this case inspect the gate tube and associated components for defects. If a sufficient voltage change fails to appear, proceed to step 3.

Step 3. Attempt to place the control circuitry in the "ready time" state by following steps (a) thru (c) above. If the DCU's do not reset, search for trouble in the reset circuitry (V205 & V206). In particular, inspect diodes CR205 and CR209. If the reset line has been accidentally shorted to ground these diodes may burn out. If the DCU's reset correctly proceed to step 4.

Step 4. See whether the reset pulse has switched the control circuit binaries to the "ready time" state. The d-c voltage at pin 1 of V202 should be about -34v; the voltage at pin 1 of V203 should be about -29v. If voltages approximating these fail to appear, check the tubes and associated circuitry, in particular R211 and R214. If adequate voltages appear, proceed to step 5.

Step 5. Try to switch the binaries to the "counting time" state by introducing a start pulse as described under (d) above. Both binaries should change state, causing the d-c voltage at pin 1 of both V102 and V203 to change to approximately +10v. If either binary fails to "flip", the tube or associated components may be at fault. The cause may also be one of the injection diodes (V201A or V201B). Check voltages and components using ordinary techniques, but do not attempt to measure grid voltages on either binary because touching a grid pin with a probe may in itself "flip" the binary. If both binaries have changed state proceed to step 6.

Step 6. Attempt to place the circuitry in the "display time" state by injecting a stop pulse as described in (e) above. The control binary should change state, causing the voltage at pin 1 of V203 to return to approximately -29v. The automatic reset action begins when a stop pulse occurs. If you adjust the counter for an automatic display period of 4 or 5 seconds, you may check this action by observing the gradually rising voltage at pin 7 of V206. The voltage there should change from zero to +22v.

TYPICAL VOLTAGES AND RESISTANCES

The following voltages and resistances appear in a Model 7360. The table is valid for all other 7000 Series instruments (Models 7150, 7160, 7250, 7260 and 7350) except that some of the tubes or other plug-in components listed will not be installed in the instrument. The resulting lower load on the power supply may cause unregulated voltage to rise 5%. Ordinarily, readings may vary ±10% from the typical value without causing trouble. Special conditions of measurement are indicated by letter superscrupts ("a", "b", "c", etc.) which refer to notes at the end of the table. Otherwise conditions are as follows:

1. Voltages measured with a VTVM having an input impedance of 11 megohms.
2. Line voltage 117 volts.
3. FUNCTION switch at OFF position.
4. TIME switch at 10^{-6}.
5. ATTENUATION controls at "DC1".
6. DISPLAY time control turned clockwise until switch clicks.
7. Instrument in "ready time" condition; that is, after reset but before a start pulse occurs.
8. No input signals coupled to the instrument.

D-C Supplies	D-C Volts with respect to ground	Resistance to ground in Ohms
Unreg B+	+210	6.0K
Reg. B+	+120	4.2K
Unreg. B-	-120	8.6K
Reg. B-	-56	7.6K

Plug-in DCU	Pin No.	D-C Volts with respect to ground	Resistance to ground in Ohms
AY201	1	Fil -120	7.6K
	2	-120	7.5K
	3	-66	8.9K
	4	+210	6.0K
	5	+210	6.0K
	6	N.C.	
	7	210	30K
	8	-120	7.1K
	9	N.C.	
	10	+13.8	∞
	11	Fil -120	7.6K

Plug-in DCU	Pin No.	D-C Volts with respect to ground	Resistance to ground in Ohms
AY202	Same as AY205		
AY203	Same as AY205		
AY204	Same as AY205		
AY205	1	Fil-120	7.5K
	2	-50	140K
	3	-120	7.5K
	4	-66	63K
	5	+210	6.0K
	6	-60	1.35M
	7	-66	63K
	8	-120	7.1K
	9	-60	1.35M
	10	-59	1.35M
	11	Fil-120	7.5K

Plug-in DCU	Pin No.	D-C Volts with respect to ground	Resistance to ground in Ohms
AY206	1	Fil-120	7.5K
	2	-50	140 K
	3	-120	7.5K
	4	-66	63K
	5	+210	6.0K
	6	-60	1.35M
	7	+80	18K
	8	-120	7.1K
	9	-60	1.35M
	10	-59	1.35M
	11	Fil-120	7.5K
AY207	1	Fil	
	2	0	900K
	3	0	0
	4	+80	18K
	5	+210	6.0K
	6	-24.5	68K
	7	+190	∞
	8	+0.55.	280[b]
	9	-29	680K
	10	-29.5	680K
	11	Fil	
Tube			
V101	1	-2.1	470K
	2	0	0
	3	Fil	
	4	Fil	
	5	+90	110K
	6	+94	26K
	7	0	0
V102	1	+90	110K
	2	+210	6.0K
	3	+120	4.2K
	4	+90	110K
	5	+210	6.0K
	6	+120	4.2K
	7	Fil	
	8	Fil	

Tube	Pin No.	D-C Volts with respect to ground	Resistance to ground in Ohms
V104	1	0	0
	2	-56	8.6K
	3	-57	700[b]
	4	Fil	
	5	Fil	
	6	0	0
	7	-56	8.6K
	8	-57	700[b]
	9	Fil	
V201	1	-91/-93/-91[c]	24K
	2	-78/-90/-78[c]	41K
	3	Fil	
	4	Fil	
	5	-75	80K
	6	N.C.	
	7	-101/-95/-101[c]	20K
V202	1	-33/+10.3/+10.3[cd]	11K
	2	-78/-90/-90[cd]	42K
	3	-78	18K
	4	Fil	
	5	Fil	
	6	+9.3/-33/+9.3[cd]	11K
	7	-90/-78/-78[cd]	42K
	8	-78	18K
	9	Fil	
V203	1	-48/-8/-48[cd]	5.8K
	2	-93/-103/-93[cd]	21K
	3	-93/-95/-93[cd]	12K
	4	Fil	
	5	Fil	
	6	-11/-54/-11[cd]	7.2K
	7	-101/-95/-101[cd]	21K
	8	-93/-95/-93[c]	12K
	9	Fil	

Tube	Pin No.	D-C Volts with respect to ground	Resistance to ground in Ohms
V204	1	-8/-7.9/-8[c]	22K
	2	0	0
	3	Fil	
	4	Fil	
	5	+188/+162/+188[c]	00
	6	112/114/112[c]	5.2K
	7	-18/+0.3/-18[c]	260[b]
V205	1	+28/+52/+205[c]	47K
	2	-0.4/-1.9/-25[c]	780K
	3	0	0
	4	Fil	
	5	Fil	
	6	-32.5/-21.5/+48[c]	46K
	7	-45/-33.5/+38[c]	570K
	8	Fil	
	9	+210	6.0K
V206	1	+110	16K
	2	+32	4.1M
	3	+32	3.3K
	4	Fil	
	5	Fil	
	6	+210	11K
	7	0/0/ to +22[ce]	7.0M
	8	+32	3.3K
	9	Fil	
V207	1	+82	16.5K
	2	+13	510K
	3	+13	1.0K
	4	Fil	
	5	Fil	
	6	+210	29K
	7	0	24K
	8	+13	1.0K
	9	Fil	

Tube	Pin No.	D-C Volts with respect to ground	Resistance to ground in Ohms
V301	1	+72/+93[f]	14.5K
	2	+1.92/-1.95[f]	
	3	+2.75/+0.85[f]	28K
	4	Fil	
	5	Fil	
	6	+93/+73[f]	14.5K
	7	0	10M
	8	+2.75/+0.85[f]	28K
	9	Fil	
V302	1	+44/+62[f]	17K
	2	+0.6/-3.6[f]	69K
	3	+0.54/+2.85[f]	20K
	4	Fil	
	5	Fil	
	6	+70/+65[f]	12K
	7	-4.8/+2.7[f]	69K
	8	+0.54/+2.85[f]	
	9	Fil	
V303	1	+110/+110[f]	4.5K
	2	+44/+62[f]	17K
	3	+110	4.5K
	4	Fil	
	5	Fil	
	6	+96/+82[f]	7.0K
	7	+58/+62[f]	
	8	+58/+62[f]	6.8K
	9	+58/+52[f]	9.5K
V401	1	+113	4.5K
	2	+3.61	11K
	3	+113	4.5K
	4	Fil	
	5	Fil	
	6	+105	6.4K
	7	+48	2.5K
	8	+1.08	550
	9	+1.08	500

Tube	Pin No.	D-C Volts with respect to ground	Resistance ground in Ohms
Y401 (Crystal)	1	117 AC	
	2	N.C.	
	3	N.C.	
	4	N.C.	
	5	0	0
	6	117 AC	0
	7	0	0
V402	1	+116	4.3K
	2	+58	11K
	3	+116	4.3K
	4	Fil	
	5	Fil	
	6	+92	6.9K
	7	+62	6.8K
	8	+62	6.8K
	9	+58	9.5K
V501	1	+107	10.5K
	2	+19	630K
	3	+31	5.0K
	4	Fil	
	5	Fil	
	6	+83	11.5K
	7	+31	30K
	8	+30.5	5.0
	9	Fil	
V502	1	+120	4.2K
	2	+3.8	7.2K
	3	+38	15K
	4	Fil	
	5	Fil	
	6	+25	4.1K
	7	+25	4.1K
	8	+31	30K
	9	Fil	

Tube	Pin No.	D-C Volts with respect to ground	Resistance ground in Ohms
V601	1	+120	4.2K
	2	+62	50K
	3	+118	4.3K
	4	Fil	
	5	Fil	
	6	+94	6.9K
	7	+64	6.8K
	8	+64	6.8K
	9	+59	9.5K
V602	1	+114	9.2K
	2	+107	10.5K
	3	Fil	
	4	Fil	
	5	+114	9.2K
	6	N.C.	
	7	+82	11.5K
V603	1	+66	26K
	2	+22	118K
	3	+24	8.2K
	4	Fil	
	5	Fil	
	6	+105	25K
	7	+8	4.0M
	8	+24	8.2K
	9	Fil	
V604	1	+104	26K
	2	+0.85	4.0M
	3	+24	8.2K
	4	Fil	
	5	Fil	
	6	+64	26K
	7	+22	118K
	8	+24	8.2K
	9	Fil	

Tube	Pin No.	D-C Volts with respect to ground	Resistance ground in Ohms
V605	1	+65	26K
	2	+22	118K
	3	+24	8.2K
	4	Fil	
	5	Fil	
	6	+105	25K
	7	+1.5	4.0M
	8	+24	8.2K
	9	Fil	
V606	1	+105	26K
	2	+3.0	4.0M
	3	+24	8.2K
	4	Fil	
	5	Fil	
	6	+63	26K
	7	+22	118K
	8	+24	8.2K
	9	Fil	

Tube	Pin no.	D-C volts with respect to ground	Resistance to ground in Ohms
V607	1	+65 ±20v[g]	26K
	2	+22 ±5[g]	118K
	3	+25 ±2[g]	8.2K
	4	Fil	
	5	Fil	
	6	+105 ±20[g]	25K
	7	0 ± 15[g]	4.0M
	8	+25 ± 2[g]	8.2K
	9	Fil	

Notes

a. This DCU is installed only on instruments which feature "X10" positions of the FUNCTION switch.

b. Resistance reading here will vary with amplitude and polarity of the voltage applied by the measuring device. This reading was obtained using an RCA type WV-98A Volt-Ohmist on the RX100 range, negative terminal grounded.

c. Three voltage reading taken: the first with the instrument in "ready time" state; the second, in "counting time" state, the third, in "display time" state.

d. This pin is connected to a binary grid or plate. If you touch the pin with a probe, the binary may "flip", thus producing a wrong reading. Therefore, when measuring the voltage here attach the probe first, then cause the instrument to pass pass through the three stable states in the operating cycle.

e. To obtain the third reading place the instrument in the "display time" state, then rotate the DISPLAY control CCW just far enough to cause the switch to click. The voltage should begin rising from ground level, reaching about +22v in approsimately five seconds.

f. Two voltage readings taken: the first with the associated TRIGGER VOLTAGE control fully clockwise; the second, with the control fully CCW.

g. This divider stage cycles so slowly that the needle of a voltmeter will wobble visibly within the range noted.

PARTS LIST MODELS 7150 & 7160 GATE & CONTROL CIRCUITRY

Refer to Dwg. No. 7150D7

ABBREVIATIONS

BDB	Berkeley Division Beckman, Richmond, Calif.	LV	Low Voltage
Cap.	Capacitor	μa	Microamps
CT	Center Tap	μh	Microhenries
CH	Cutler-Hammer Co., Milwaukee, Wisconsin	ma	Milliamps
DC	Deposited Carbon	mh	Millihenries
DCU	Decimal Counting Unit	Pot.	Potentiometer
FC	Fixed Composition	RCA	Radio Corporation of America, Harrison, New Jersey
GE	General Electric, Schenectady, New York	Res.	Resistor
Gen. Ind.	General Industries, Elyria, Ohio	USECO	U.S. Engineering Company, Glendale, California
HV	High Voltage	VDC	Volts Direct Current
IPC	Industrial Products Co., Danbury, Connecticut	WW	Wire Wound
IRC	International Rectifier Corp, El Segundo, Calif.		

NOTE: Any resistor which does not appear in the list below is a fixed composition resistor of the value, wattage and tolerance noted on the schematic diagram. All other electrical components are listed.

Detail No.	Berkeley Stock No.	Description	Manufacturer & No.
AY202, AY203 AY204, AY205 & AY206		DCU, Model 705 AH	BDB
AY207		DCU, Model 707AH	BDB (not on Model 7150)
C201	2-2137	Cap., 500 Mmfd, Mica	Sangamo RR 1350
C202	2-2136	Cap., 25 Mmfd, Mica	Sangamo RR 1425
C203	2-2760	Cap., .25 Mfd, 400 V, Paper	Sangamo 3004025
C204	2-4388	Cap., .01 mf, Disc, Axial Lead	Sprague (2-2230 may be used)
C205		Same as C202	
C206		Same as C201	
C207		Same as C202	
C208		Same as C202	
C209		Same as C204	
C210		Same as C202	
C211		Same as C202	
C212		Same as C201	
C213	2-2230	Cap., .01 mfd, Disc	Erie 811
C214& C215	2-5691	Cap., .1 mfd, 400 V, Metalized Paper	Hopkins Eng. P140
C216	2-8122	Cap., 1 mfd, 200 V	Sprague 2TM-M1
C217		Same as C213	
C218		Same as C213	
C219		Same as C201	
C220	2-2136	Cap., 100 Mmfd, Mica	Sangamo RR 1310
C221	2-2141	Cap., 50 Mmfd, Mica	Sangamo RR 1450
C222	2-2136	Cap., 100 Mmfd, Mica	Sangamo RR 1310
C223	2-5793	Cap., .001 mfd, Disc.	Centralab DD 102
C224, C225, C226, C227, C228, C229, C230, C231, C232, C233, C234, C235, C236, C237, C238, C239, C240, C241, C242, C243, C244, C245, C246		Same as C223	

Detail No.	Berkeley Stock No.	Description	Manufacturer & No.
CR201, CR202 & CR203	8-5578	Crystal Diode, 9GA2	IRC
CR204	8-5580	Crystal Diode, 1N95	Hughes Aircraft
CR205	8-4128	Crystal Diode, 1N98	Hughes Aircraft
CR206		Same as CR201	
CR207		Same as CR204	
CR208		Same as CR204	
CR209		Same as CR204	
J202	17-5620	Connector, 40 pin Chassis Mtg.	Cannon DPX-40-34S
J203	17-3295	Connector, Jack Nylon Black	Johnson 105-603-2
R247	1-2955	Potentiometer, 10M, with switch	CRL BA026-000
S201	12-6029B	Switch, 4 sec, 4 pos, rotary	
S202 & S203	12-1909 12-1641	Switch, DPDT Switch, SPDT	CH 8373K7 CH 8282K13
S204		On back of R247	
S205	12-2600	Switch, Reset DPDT Push	Switchcraft #FF1006
V201	5-0978	Tube, 6AL5	RCA
V202 & V203	5-3301	Tube, 5965	RCA
V204	5-0506	Tube, 6AS6	RCA
V205	5-2129	Tube, 5687	Tung Sol
V206		Same as V202	
XAY201 & 4-1720 XAY202, XAY203, XAY204, XAY205, XAY206, XAY207		Socket, 11 Pin	Amphenol 77MIP11
XV201	4-2972	Socket, 7 Pin w/o Shield w/lugs	Elco 316BC
XV202, XV203	4-2973	Socket, 9 Pin w/o Shield w/lugs	Elco 377BC
XV204		Same as XV201	
XV205		Same as XV202	
XV206		Same as XV202	
XV207	4-1720	Same as XV202	
	18-0776	Cable Assembly Model 776	BDB

ADDITIONS

CR210	8-4184	Diode, 1N67A
L202	3-6164	Coil, 500 Micro henry
R268	1-1166A	8.2K, 1/2 W, 5 %

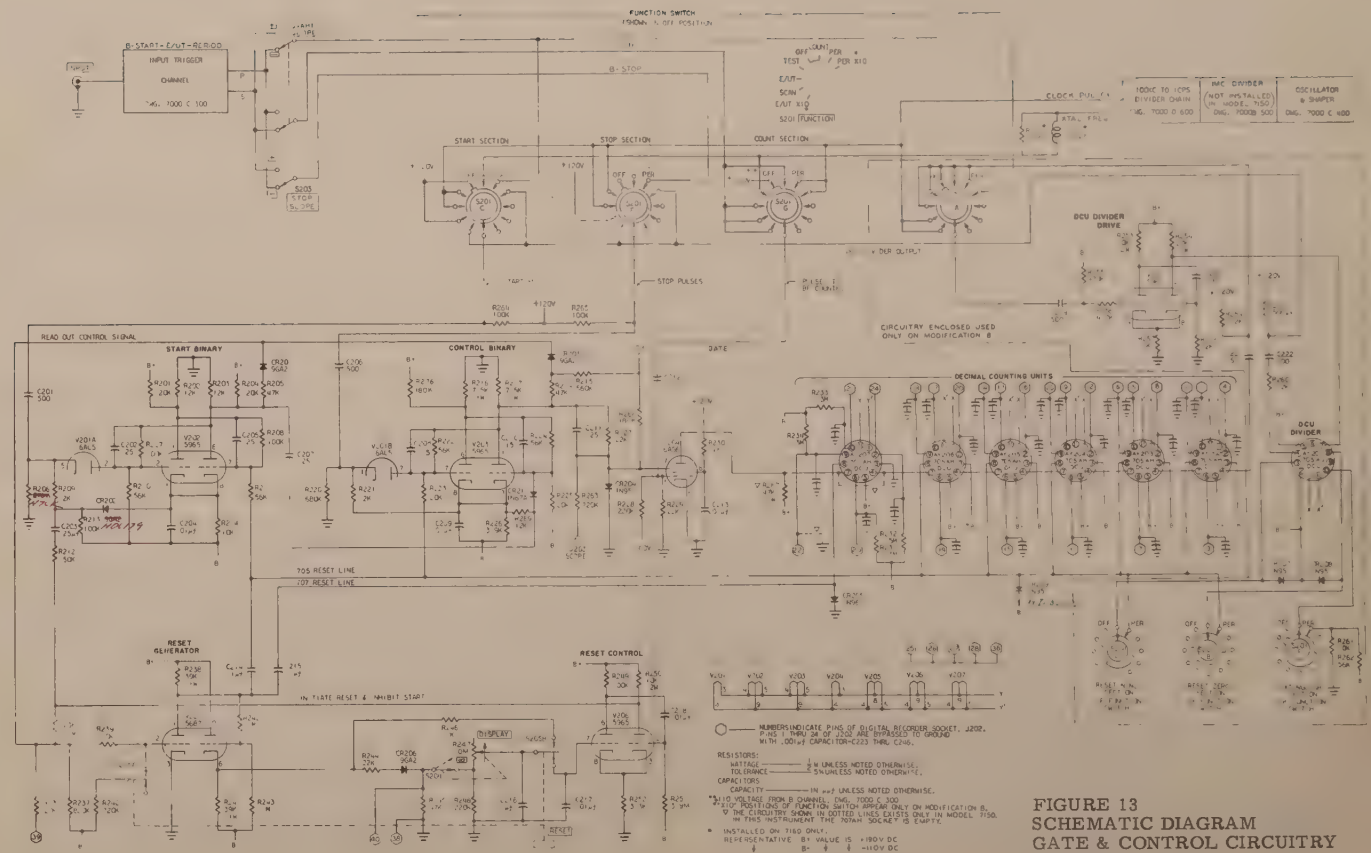


FIGURE 13
SCHEMATIC DIAGRAM
GATE & CONTROL CIRCUITRY
MODELS 7150 & 7160
DWG. NO. 7150D7

PARTS LIST, INPUT CHANNEL, MODELS 7150 & 7160

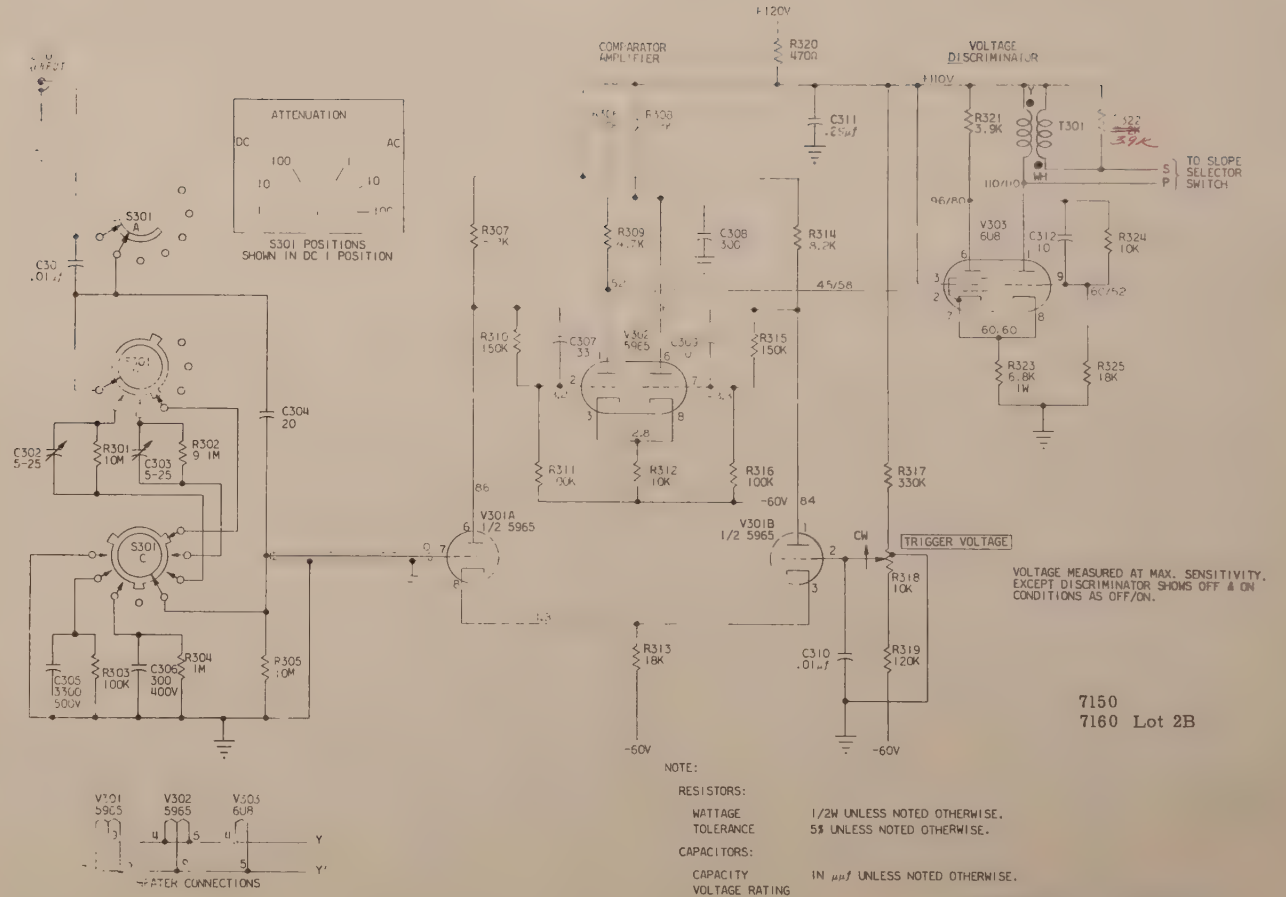
Refer to Dwg. No. 7000C300

ABBREVIATIONS

AB	Allen-Bradley Company, Milwaukee, Wisconsin		
BDB	Berkeley Division Beckman, Richmond, Calif	LV	Low Voltage
Cap.	Capacitor	μa	Microamps
CT	Center Tap	μh	Microhenries
CH	Cutler-Hammer Co., Milwaukee, Wisconsin	ma	Milliamps
DC	Deposited Carbon	mh	Millihenries
DCU	Decimal Counting Unit	Pot.	Potentiometer
FC	Fixed Composition	RCA	Radio Corporation of America, Harrison, New Jersey
GE	General Electric, Schenectady, New York	RES.	Resistor
Gen. Ind.	General Industries, Elyria, Ohio	USECO	U.S. Engineering Company, Glendale, California
HV	High Voltage	VDC	Volts Direct Current
IPC	Industrial Products Co., Danbury, Connecticut	WW	Wire Wound

Detail No.	Berkeley Stock No.	Description	Manufacturer & No.
C301	2-2230	Cap., .01 μfd, ceramic disc	Erie 811
C302 & C303	2-2426	Capacitor, 5-25 μμfd, Variable	Erie 557-5
C304	2-1039	Capacitor, 20 μμfd, Mica	Sangamo RR 1420
C305	2-6474	Capacitor, 3300 μμfd, Mica	Sangamo CR 1223
C306	2-2606	Capacitor, 300 μμfd, Mica	Sangamo RR 1330
C307	2-2607	Cap., 33 μμfd, Mica	Sangamo RR 1433
C308	2-2608	Cap., 300 μμfd, Mica	Sangamo RR 1330
C309	2-2082	Cap., 10 μμfd, Mica	Sangamo RR 1410
C310	2-2230	Cap., .01 μfd, Disc	Erie 811
C311	2-5747	Cap., .25 Mfd, 200 V Metalized	Hopkins Eng.
C312		Same as C309	
J301 & J302	17-3179	Connector, Low Voltage	IPC MS 595
R301	1-1182	Resistor, 10 M, 1/2 W, 5 %	AB EB 1065
R302	1-3572	Resistor, 9.1 M 1/2 W, 5 %	AB EB 9155
R303	1-0960	Resistor, 100 K, 1/2 W, 5 %	AB EB 1045
R304	1-0225A	Resistor 1 M, 1/2 W, 5 %	AB EB 1055
R305	1-1182	Resistor, 10 Meg. 1/2 W 5 %	AB EB 1065
R306	1-2489	Res. 1.8 K, 1/2 W, 5 %	AB EB 1825
R307	1-1166A	Res. 8.2 K, 1/2 W, 5 %	AB EB 8225
R308	1-2396	Res., 6.8 K, 1/2 W, 5 %	AB EB 6825
R309	1-1164A	Res., 4.7 K, 1/2 W, 5 %	AB EB 4725
R310	1-1154A	Res. 150 K, 1/2 W, 5 %	AB EB 1545
R311	1-0960	Res., 100 K, 1/2 W, 5 %	AB EB 1045
R312	1-0210A	Res., 10 K, 1/2 W, 5 %	AB EB 1035
R313	1-1169A	Res., 18 K, 1/2 W, 5 %	AB EB 1835
R314		Same as R307	
R315		Same as R310	
R316		Same as R311	
R317	1-1212	Res., 330 K, 1/2 W, 5 %	AB EB 3345
R318	1-5573	Potentiometer, 10 K, Tapped	AB JU 1031
R319	1-1095	Res., 120 K, 1/2 W, 5 %	AB EB 1245
R320	1-3210	Res., 470 Ω, 1/2 W, 5 %	AB EH 4715
R321	1-3609	Res., 3.9 K, 1/2 W, 5 %	AB EB 3925
R322	1-5598	Res., 2.2 K, 1/2 W, 5 %	AB EH 2225
R323	1-5079	Res., 6.8 K, 1 W, 5 %	AB EB 6821
R324		Same as R312	
R325	1-1169A	Res., 18 K, 1/2 W, 5 %	AB EB 1835
R326	1-0225A	Res., 1M, 1/2 W, 5 % fixed composition	
S301	12-3698	Switch, 2 Sec., 7 Pos.	
T301	6-5821	Transformer, Pulse 300 μ H	Pulse Eng.
V301 & V302	5-3301	Tube, 5965	RCA
V303	5-2526	Tube, 6U8	GE
XV301, XV302 & XV303	4-2973	Socket, 9 Pin W/O Shield W/ Lugs	Elco 377BC
	0-2013	Wire RG-62/U	Belden

ADDITIONS



SCHEMATIC DIAGRAM
INPUT TRIGGER CHANNEL
MODELS 7160 & 7150
Dwg. No. 7000C300

PARTS LIST, DIVIDER CHAIN, MODEL 7150

Refer to Dwg. No. 7000B500 & 7000D600

ABBREVIATIONS

AB	Allen-Bradley Company, Milwaukee, Wisconsin
Cap.	Capacitor
Pot.	Potentiometer
USECO	U.S. Engineering Company, Glendale, California

NOTE: Any resistor which does not appear in the list below is a fixed composition resistor of the value, wattage and tolerance noted on the schematic diagram. All other electrical components are listed.

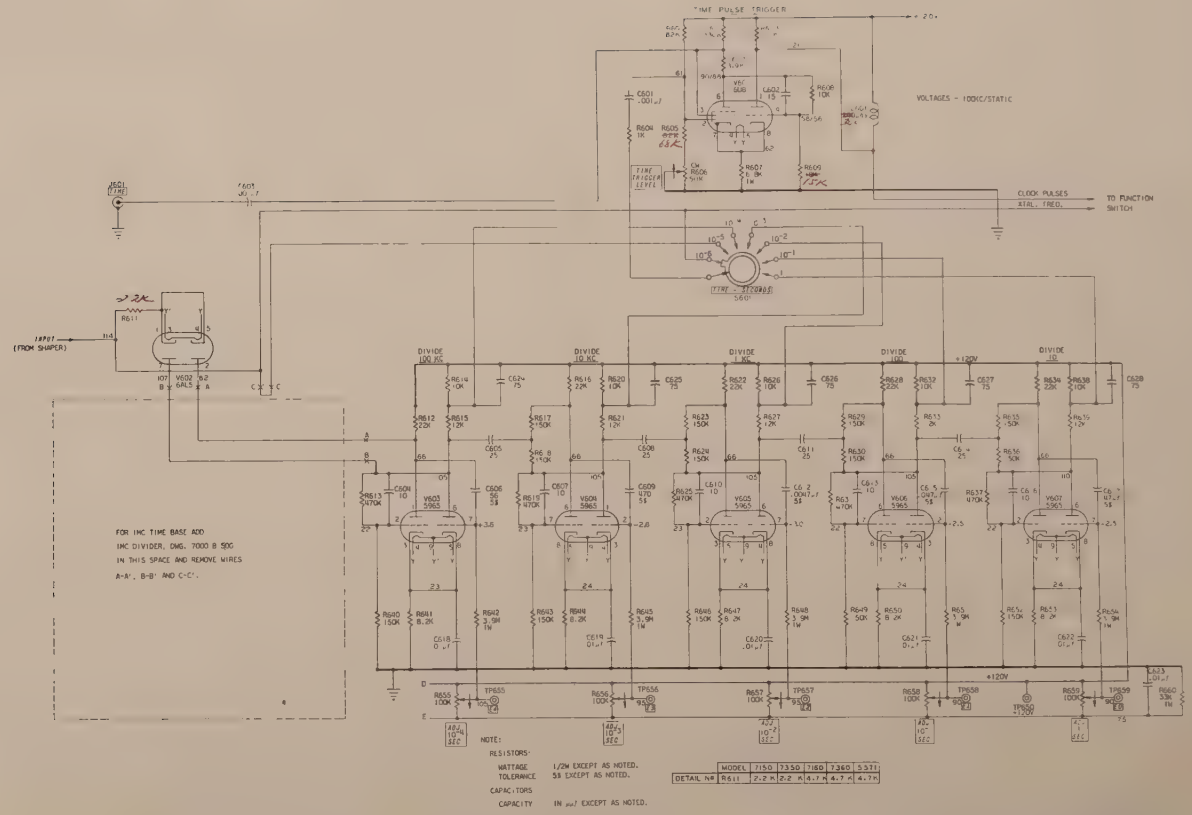
100KC TO 1CPS DIVIDER CHAIN

Detail No.	Stock No.	Description	Manufacturer & No.
C601	2-4[illegible]	Cap., .001 μfd, tubular ceramic	Erie GPK
C602	[illegible]	Cap., 15 μμfd, Mica	Sangamo RR 1415
C603		Same as C601	
C604	[illegible]	Cap., 10 μμfd, Mica	Sangamo RR 1410
C605	[illegible]	Cap., 25 μμfd, Mica	Sangamo RR 1425
C606	2-3871	Cap., 56 μμfd, 500 V, 5 % ceramic	Vitramor type 70
C607		Same as C604	
C608		Same as C605	
C609	2-3574	Cap., 470 μμfd, 500 V, 5 % ceramic	Vitramon type 70
C610		Same as C604	
C611		Same as C605	
C612	2-4206	Cap., .0047 μfd, 5%, subminiature paper	Sprague 186-P-472-53S3
C613		Same as C604	
C614		Same as C605	
C615	2-5603	Cap., .047 μfd, 5 % subminiature	Sprague 186-P-473-53S3
C616		Same as C604	
C617	[illegible]	Cap., .47 μfd, 5%, subminiature	Sprague 186-P-474-53S3
C618	2-2236	Cap., .01 μfd, Disc, ceramic	Erie 811
C619		Same as C618	
C620		Same as C619	
C621 to C623		Same as C618	
J601	17-3179	Connector BNC	

Detail No.	Stock No.	Description	Manufacturer & No.
L601	3-6238	Choke, 240 μHenry Coil	Wilco #3240-15
R642	1-6010	Resistor, 3.9 M, 1 W, 5 % DC	Electra
R648		Same as R642	
R651		Same as R642	
R654		Same as R642	
R655	1-1340	Pot., 100 K	AB JU 1041 DS 3048
R656		Same as R655	
R680	1-4509	33 K, 1 W, Deposited Carbon 5%	
S601	12-5700	Switch, 7 Pos, 1 Pole	
V601	5-2626	Tube, 6U8	
V602	5-0878	Tube, 6AL5	
V603 to V607	5-3301	Tube, 5965	
XV601	4-2973	Socket, 9 Pin W/O Shield W/Lugs	Elco 377 BC
XV602	4-2972	Socket, 7 Pin W/O Shield W/Lugs	Elco 316 BC
XV603 to XV607		Same as XV601	
	17-3294	Tip jack	Johnson 105-602-2
	24-1721	Lock, Shaft	USECO 1510
	24-3788	Shaft, Flexible 4" long	Kupfrian 1598F

ADDITIONS

C624 to C628 2-1706A Cap., 75 μμfd, 500 V


TIME PULSE TRIGGER
VOLTAGES - 100KC/STATIC
CLOCK PULSES
XTAL. FREQ.
TO FUNCTION SWITCH
J601 (FROM SHAPER)
FOR INC TIME BASE ADD INC DIVIDER, DWG. 7000 B 500 IN THIS SPACE AND REMOVE WIRES A-A', B-B' AND C-C'.
DIVIDE BY 10
+120V
NOTE:
RESISTORS:
WATTAGE 1/2W EXCEPT AS NOTED.
TOLERANCE 5% EXCEPT AS NOTED.
CAPACITORS
CAPACITY IN μμf EXCEPT AS NOTED.
MODEL 7150 7350 7160 7360 5371
DETAIL No. R611 2.2 K 2.2 K 4.7 K 4.7 K 4.7 K

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SCHEMATIC DIAGRAM
DIVIDER CHAIN
MODEL 7150
Dwg. No. 7000D600

PARTS LIST, DIVIDER CHAIN, MODEL 7160

Refer to Dwg. No. 7000B500 & 7000D600

ABBREVIATIONS

AB	Allen-Bradley Company, Milwaukee, Wisconsin
Cap.	Capacitor
Pot.	Potentiometer
USECO	U.S. Engineering Company, Glendale, California

NOTE: Any resistor which does not appear in the list below is a fixed composition resistor of the value, wattage and tolerance noted on the schematic diagram. All other electrical components are listed.

100KC TO 1CPS DIVIDER CHAIN

Detail No.	Stock No.	Description	Manufacturer & No.
C600	2-3242	Cap., .001 μfd, tubular ceramic	Erie GPK
C602	2-2135	Cap., 15 μμfd, Mica	Sangamo RR 1415
C603		Same as C601	
C604	2-2082	Cap., 10 μμfd, Mica	Sangamo RR 1410
C605	2-2138	Cap., 25 μμfd, Mica	Sangamo RR 1425
C606	2-3879	Cap., 56 μμfd, 500 V, 5 % ceramic	Vitramon type 70
C607		Same as C604	
C608		Same as C605	
C609	2-3574	Cap., 470 μμfd, 500 V, 5 %, ceramic	Vitramon type 70
C610		Same as C604	
C611		Same as C605	
C612	2-4206	Cap., .0047 μfd, 5%, subminiature paper	Sprague 186-P-472-53S3
C613		Same as C604	
C614		Same as C605	
C615	2-5603	Cap., .047 μfd, 5 %, subminiature	Sprague 186-P-473-53S3
C616		Same as C604	
C617	2-5604	Cap., .47 μfd, 5%, subminiature	Sprague 186-P-474-53S3
C618	2-2230	Cap., .01 μfd, Disc, ceramic	Erie 811
C619		Same as C618	
C620		Same as C619	
C621 to C623		Same as C618	
J601	17-3179	Connector BNC	

Detail No.	Stock No.	Description	Manufacturer & No.
L601	3-6238	Choke, 240 μHenry Coil	Wilco #3240-15
R642	1-6010	Resistor, 3.9 M, 1 W, 5 % DC	Electra
R648		Same as R642	
R651		Same as R642	
R654		Same as R642	
R655	1-1340	Pot., 100 K	AB JU 1041 DS 3048
R656 to R658		Same as R655	
R660	1-4509	33 K, 1 W, Deposited Carbon 5%	
S601	12-5700	Switch, 7 Pos, 1 Pole	
V601	5-2526	Tube, 6U8	
V602	5-0978	Tube, 6AL5	
V603 to V607	5-3301	Tube, 5965	
XV601	4-2073	Socket, 9 Pin W/O Shield W/Lugs	Elco 377 BC
XV602	4-2972	Socket, 7 Pin W/O Shield W/Lugs	Elco 316 BC
XV603 to XV607		Same as XV601	
	17-3294	Tip jack	Johnson 105-602-2
	24-1721	Lock, Shaft	USECO 1510
	24-5789	Shaft, Flexible 4" long	Kupfrian 1598F

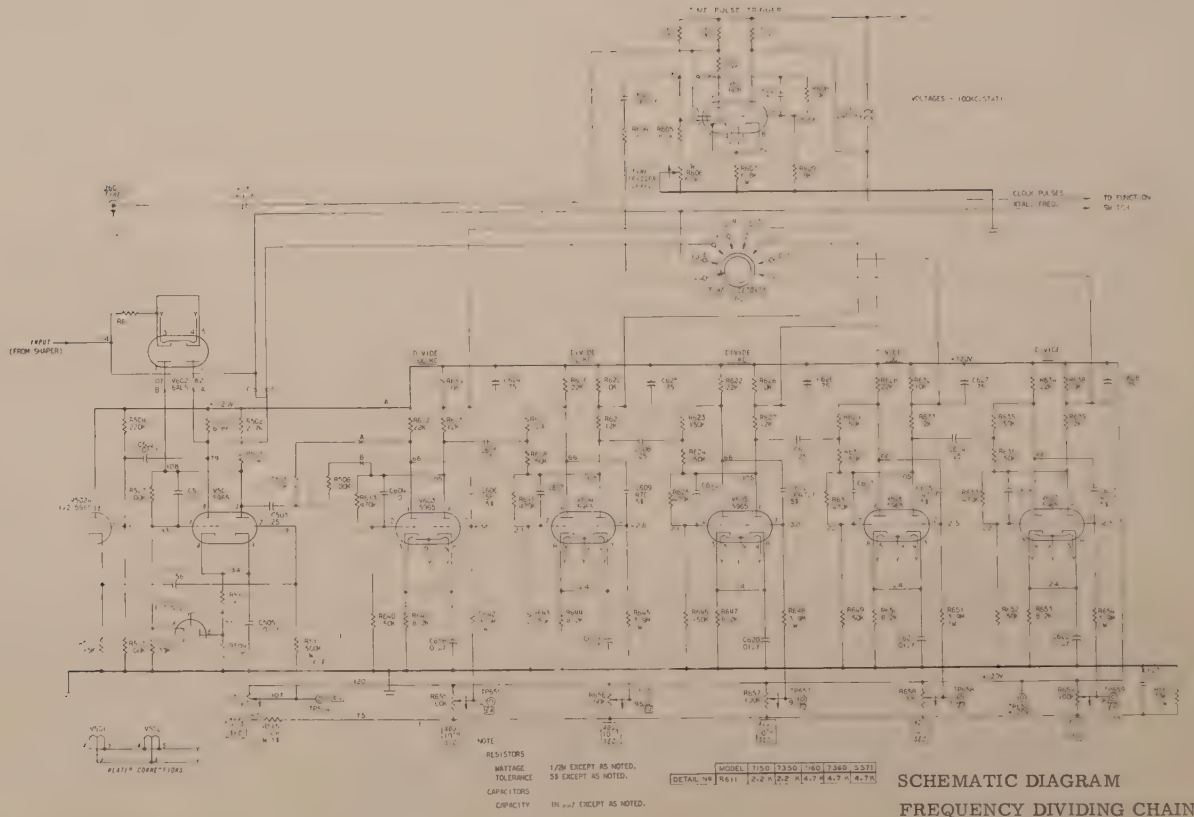
1MCS TO 100KCS DIVIDER

Detail No.	Stock No.	Description	Manufacturer & No.
C501	2-2082	Cap., 10 μμfd, Mica, silvered	Sangamo RR 1410
C502	2-2230	Cap., .01 μfd, Disc ceramic	Erie 811
C503	2-2138	Cap., 25 μμfd, Mica, silvered	Sangamo RR 1425
C504	2-3879	Cap., 56 μμfd, 5 %, ceramic	Vitramon Type 10
C505		Same as C502	
R514	1-1340	Pot., 100 K, 2 W, 10 %, carbon linear	AB JU 1041 SD 3048

Detail No.	Stock No.	Description	Manufacturer & No.
R515	1-6844	Resistor 50 K, 1 W, 5 % deposited carbon	Electra DCF
TP	17-3294	Tip jack, nylon	Johnson 105-602-2
V501 & V502	5-3301	Tube, 5965	
XV501 & XV502	4-2973	Socket, 9 Pin W/O Shield W/Lugs	Elco 377BC

ADDITIONS

C624 to C628 2-1706A Cap., 75 μμfd, 500 V



SCHEMATIC DIAGRAM
FREQUENCY DIVIDING CHAIN
Model 7160
Dwgs. No. 7000B500 & 7000D600

PARTS LIST, OSCILLATOR & SHAPER MODELS 7150 & 7160

Refer to Dwg. No. 7000 C400

ABBREVIATIONS

AB	Allen-Bradley Company, Milwaukee, Wisconsin
BDB	Berkeley Division Beckman, Richmond, Calif.
CH	Cutler-Hammer Co., Milwaukee, Wisconsin
FC	Fixed Composition
IPC	Industrial Products Co., Danbury, Connecticut
Pot.	Potentiometer
RCA	Radio Corporation of America, Harrison, New Jersey

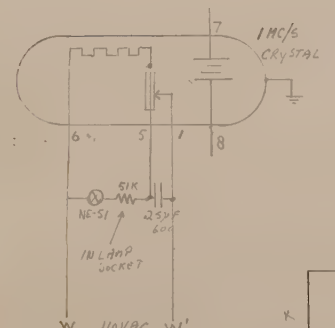
Detail No.	Stock No.	Description	Manufacturer & No.
C401	2-2230	Capacitor, .01 µfd, Disc.	Erie #811
C402	2-3242	Capacitor, .001 µfd, tubular ceramic	Erie GPK
C403 (Model 7150)	2-3245	Capacitor, 600 µµfd, 500 V	Sangamo KR 1360
C403 (Model 7160)	2-3620	Capacitor, 120 µµfd, Mica	Sangamo RR 1312
C404 to C406		Same as C401	
C407	2-2135	Capacitor, 15 µµfd, 500 vdc, silvered Mica	Sangamo RR 1415
C408	2-3843	Capacitor, .1 µfd, plastic molded paper	CD Tiny Chief
C409	2-3106	Capacitor, 33 µµfd, tubular ceramic	Erie NPO
C410 (Model 7150)	2-1501	Capacitor, 0-100 µµfd, Variable	Millen
C410 (Model 7160)	2-5706	Capacitor, 2-18 µµfd, Variable	JFD VC4
I402	21-5861	Lamp, 24 V, .033 to .045 amp.	24B-2
J401	17-3179	Connector, BNC	IPC MS 595
L401 (Model 7150)	3-6344	Choke, 2.5-5 Milli Henry As per Spec. Dwg.	Essex Elect.
L401 (Model 7160)	3-3511	Choke, 190-210 µ Henry as per Spec. Dwg.	Pulse Engineering
R401	1-0209A	Resistor, 1 K, 1/2 W, 5 % , FC	AB EB 1025
R402	1-2489	Resistor, 1.8 K, 1/2 W, 5 %FC	AB EB 1825
R403	1-3210	Resistor, 470 Ω, 1/2 W, 5 %,FC	AB EB 4715
R404	1-3909	Resistor, 3.9 K, 1/2 W, 5 %,FC	AB EB 3925
R405	1-1169A	Resistor, 18 K, 1/2 W, 5 % .FC	AB EB 1835
R406	1-5598	Resistor, 2.2 K, 1/2 W, 5 %,FC	AB EB 2225

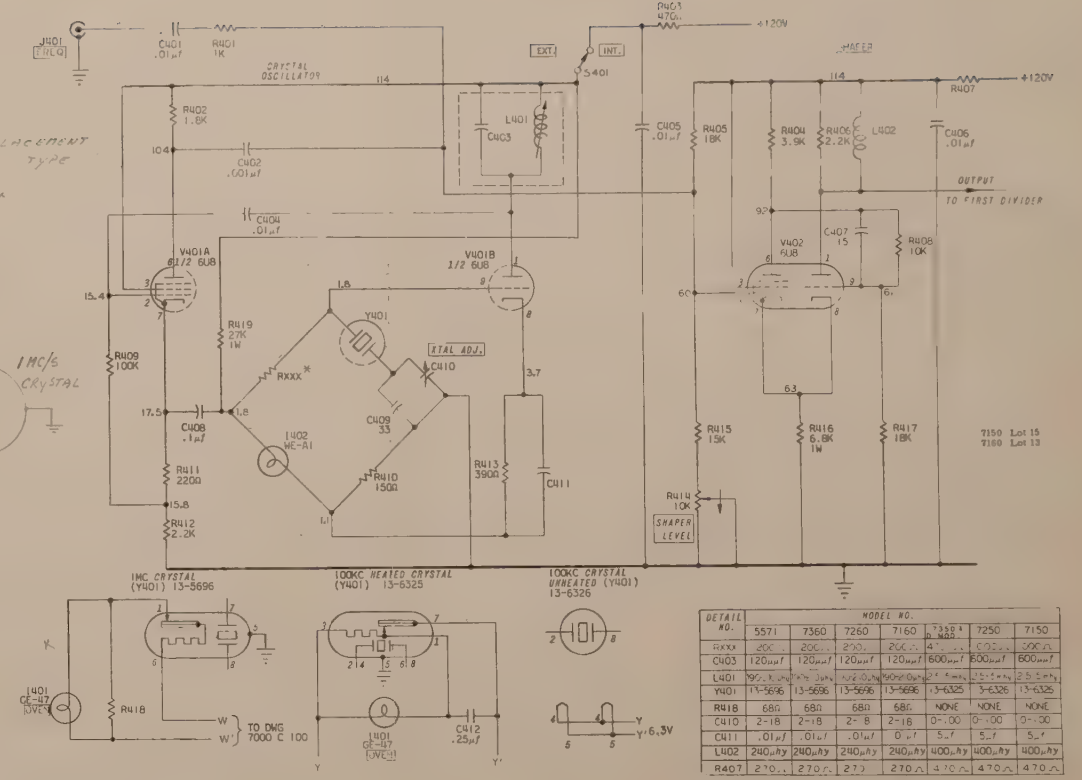
Detail No.	Stock No.	Description	Manufacturer & No.
R407 (Model 7150)	1-3210	Resistor, 470 Ω, 1/2 W, 5 %	AB EB 4715
R407 (Model 7160)	1-4274	Resistor, 270 Ω, 1/2 W, 5 %	AB EB 2715
R408	1-0210A	Resistor, 10 K, 1/2 W, 5%,FC	AB EB 2225
R409	1-0960	Resistor, 100 K, 1/2 W, 5%,FC	AB EB 1045
R410	1-4388	Resistor, 150 Ω, 1/2 W, 5 %,FC	AB EB 1515
R411	1-5597	Resistor, 220 Ω, 1/2 W, 5 %,FC	AB EB 2215
R412		Same as R406	
R413	1-5902	Resistor, 390 Ω, 1/2 W, 5 %,FC	AB EB 3915
R414	1-0875	Pot., 10 K, 2 W, 10 %, carbon linear	AB JU 1031
R415	1-1168A	Resistor, 15 K, 1/2 W, 5 %FC	AB EB 1535
R416	1-5079	Resistor, 6.8 K, 1 W, 5 %,FC	AB GB 6825
R417		Same as R405	
R418	1-4418	Resistor, 68 Ω, 2 W, 5 %	AB HB 6805
R419	1-0341	Resistor, 27 K, 1 W, 5 % , FC	AB GB 2735
S401	12-1843	Switch, SPST	CH 8280K15
V401 & V402	5-2525	Tube, 6U8	RCA
XV401 & XV402	4-3345	Socket, 9 Pin W/Shield	
XY401	4-3213	Socket, Octal, Mica filled	Cinch Jan
Y401 (Model 7150)	13-6326	Crystal, 100 KC as per Spec. Dwg.	James Knight
Y401 (Model 7160)	13-5696	Crystal, 1 Mc W/Oven as per Spec. Dwg.	James Knight

ADDITIONS

OVEN CIRCUIT MODIFIED AS SHOWN BELOW TO ACCOMODATE REPLACEMENT TYPE

20 NOV 1964





DETAIL NO.	MODEL NO. 5571	7360	7260	7160	7350 (Mod. 7150)	7250	7150
RXXX	200	200	270	200 Ω	470 Ω	500 Ω	500 Ω
C403	120µµf	120µµf	120µµf	120µµf	600µµf	600µµf	600µµf
L401	190-210µHy	190-210µHy	190-210µHy	190-210µHy	2.5-5 mHy	2.5-5 mHy	2.5-5 mHy
Y401	13-5696	13-5696	13-5696	13-5696	13-6325	13-6326	13-6325
R418	68Ω	68Ω	68Ω	68Ω	NONE	NONE	NONE
C410	2-18	2-18	2-18	2-18	0-.00	0-.00	0-.00
C411	.01µf	.01µf	.01µf	0µf	5µf	5µf	5µf
L402	240µHy	240µHy	240µHy	240µHy	400µHy	400µHy	400µHy
R407	270Ω	270Ω	270	270Ω	470Ω	470Ω	470Ω

NOTE

RESISTORS:
WATTAGE 1/2W UNLESS OTHERWISE NOTED.
TOLERANCE 5% UNLESS OTHERWISE NOTED.

CAPACITORS:
CAPACITY IN µµf UNLESS OTHERWISE NOTED.

* VALUE SELECTED FOR INDIVIDUAL INSTRUMENT SEE TABLE FOR APPROXIMATE RESISTANCE.

SCHEMATIC DIAGRAM
MODELS 7160 & 7150
OSCILLATOR & SHAPER
Dwg. No. 7000C400

PARTS LIST, MODELS 7150 & 7160 POWER SUPPLY

Refer to Dwg. No. 7000C100

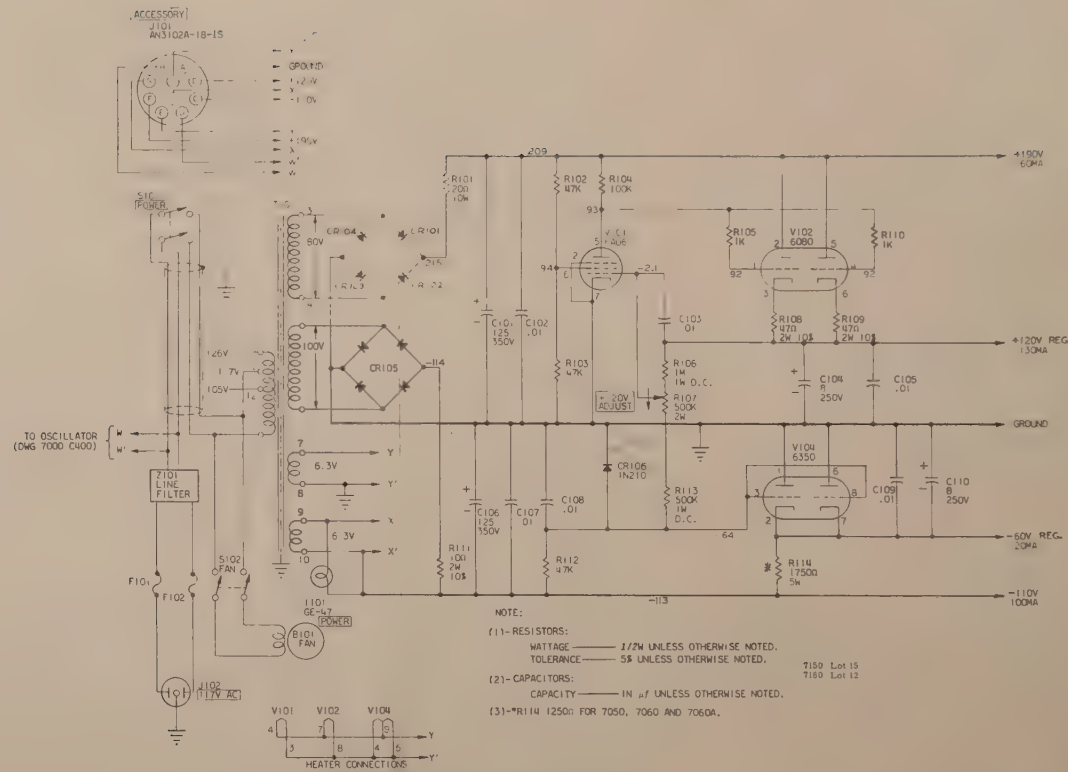
ABBREVIATIONS

AB	Allen-Bradley Company, Milwaukee, Wisconsin		
BDB	Berkeley Division Beckman, Richmond, Calif.	LV	Low Voltage
Cap.	Capacitor	μa	Microamps
CT	Center Tap	μh	Microhenries
CH	Cutler-Hammer Co., Milwaukee, Wisconsin	ma	Milliamps
DC	Deposited Carbon	mh	Millihenries
DCU	Decimal Counting Unit	Pot.	Potentiometer
FC	Fixed Composition	RCA	Radio Corporation of America, Harrison, New Jersey
GE	General Electric, Schenectady, New York	Res.	Resistor
Gen. Ind.	General Industries, Elyria, Ohio	USECO	U.S. Engineering Company, Glendale, California
HV	High Voltage	VDC	Volts Direct Current
IPC	Industrial Products Co., Danbury, Connecticut	WW	Wire Wound

Detail No.	Berkeley Stock No.	Description	Manufacturer & No.
B101	9-3389	Fan Motor	General Industries A8CW
C101	2-4254	Capacitor, 125 μfd, 350 V	Mallory FP 140
C102 & C103	2-2330	Capacitor, .01 μfd, Disc.	Erie Type 811
C104	2-3982	Capacitor, 8 μfd, 250 V Elect-lytic	Sangamo MT 2508
C105		Same as C102	
C106		Same as C101	
C107, C108 C109		Same as C102	
C110		Same as C104	
CR101	8-5632	Rectifier	GE 6RS22PB5AA1
CR103	8-S5633	Rectifier, 110 V, RMS, 110V, DC 130 MA	GE 6RS21PB3AT1
CR106	8-S4369	Rectifier, 1N210 as per spec.	National Semi-Cond.
F101 & F102		Fuse, 3 Amp, Slo Blo	
I101	21-1677	Lamp	GE 47
J101	17-1685	Connector, AN 3102A-18-1S	Cannon
J102	17-3185	Connector, #7486	Hubbell
R101	1-2927	Res., 20 ohms, 10 W	Tru-Ohm FRL 10
R102 & R103	1-0214	Res., 47 K, 1/2 W, 5 %	AB EB 4735
R104	1-0960	Res., 100 K, 1/2 W, 5 %	AB EB 1045
R105	1-0209A	Res., 1K, 1/2 W, 5 %	AB EB 1025

Detail No.	Berkeley Stock No.	Description	Manufacturer & No.
R106	1-5257	Res., 1 M, 1 W, 5 % DCF	Stemag Type A2
R107	1-2905	Pot., 500 K, 2 W	AB JU 5041
R108 & R109	1-2961	Res. 47 ohms, 2 W, 10 %	AB HB 4701
R110		Same as R105	
R111	1-5628	Res., 10 ohms, 2 W, 10 %	AB HB 1001
R112		Same as R102	
R113	1-6258	Res., 500 K, 1 W, 5 %, DCF	Stemag Type A1
R114	1-6237	Res., 1750 ohms, 5 W Power W.W.	Tru-Ohm FRL
S101	12-1642	Switch, DPST Bat Toggle	CH 8370 K8
S102	12-3851	Switch, DPST	CH 8270K7
T101	6-6333	Transformer, Power as per spec. dwg.	Electro
V101	5-0550	Tube, 6AU8	RCA
V102	5-2625	Tube, 6080	RCA
V104	5-5631	Tube, 6350	RCA
XF101 & XF102	4-3154	Fuse Post,	Bussman HKP
XI101	4-1678	Lamp Socket, Green Faceted	Dialco 81410-132
XV101	4-2972	Socket, 7 Pin	Elco 316 BC
XV102	4-2377	Socket, Octal	Cinch 9950
XV104	4-2973	Socket, 9 Pin	Elco 377 BC
	10-0407	Cable 8424	
	10-6506	Cord Set, End Hubbell #7484 (B/3 SJ6 one end model #73 other	Corrish
	24-[illegible]97	Clamp, AN 3057-10A	Cannon
	24-[illegible]19	Fan Blade, 5 1/2 "	Torrington

ADDITIONS



DETAIL NO.	MODEL	5571	7360	7260	7160	7350	7250	7150
	F101	4A	4A	4A	4A	3A	3A	3A
	F102	4A	4A	4A	4A	3A	3A	3A
	Z101	SPRAGUE 64864	NONE	NONE	NONE	NONE	NONE	NONE

SCHEMATIC DIAGRAM
MODELS 7160 & 7150
POWER SUPPLY
Dwg. No. 7000C100

INSTRUCTION MANUAL

Models 705AH, 705AJ & 705AK
DECIMAL COUNTING UNITS

Lot No.

BERKELEY division
Beckman Instruments, Inc.

Richmond 4, California
18 March 1957

WARRANTY

Instruments sold by Berkeley Division, Beckman Instruments, Inc., (hereafter called "the Company") are warranted only as stated below.

Subject to the exceptions and upon the conditions specified below, the Company agrees to correct, either by repair, or, at its election, by replacement, any defect of material or workmanship which develops within one year after delivery of the instrument to the original purchaser by the Company or by an authorized representative, provided that investigation and factory inspection by the Company discloses that such defect developed under normal and proper use.

The exceptions and conditions mentioned above are the following:

(a) All instruments claimed defective must be returned to the Company, transportation charges prepaid, and will be returned to the customer with the transportation charges collect.

(b) The Company makes no warranty concerning components or accessories not manufactured by it, such as tubes, fuses, batteries, etc. However, in the event of the failure of any component or accessory not manufactured by the Company, the Company will give reasonable assistance to the purchaser in obtaining from the respective manufacturer whatever adjustment is reasonable in the light of the manufacturer's own warranty.

(c) The Company shall be released from all obligations under its warranty in the event repairs or modifications are made by persons other than its own service personnel or authorized representatives' personnel unless such repairs by others are made with the written consent of the Company.

(d) Except as stated above, the Company makes no warranty, express or implied (either in fact or by operation of law), statutory or otherwise; and, except to the extent stated above, the Company shall have no liability under any warranty, express or implied (either in fact or by operation of law), statutory or otherwise.

(e) The Company expressly disclaims any liability to its customers, dealers, and to users of its products, and to any other person or persons for consequential damages of any kind and from any cause whatsoever arising out of or in any way connected with the manufacture, sale, repair, replacement of, or arising out of or in any way connected with the use of any of its products.

(f) Representations and warranties made by any person, including representatives of the Company, which are inconsistent or in conflict with the terms of this warranty (including but not limited to the limitation of the liability of the Company as set forth above) shall not be binding upon the Company unless reduced to writing and approved by an officer of the Company.

(g) This warranty shall be governed by the laws of the State of California.

Claims for damage in shipment should be filed promptly with the transportation company.

All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate. Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, Berkeley division of Beckman Instruments, Inc., Richmond 4, California.

REPAIR SERVICE

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing. Repair work will be performed only upon receipt of a written purchase order or authorization. Instruments to be repaired should be addressed to SERVICE AND REPAIR DEPARTMENT with transportation charges prepaid. Repaired instruments will be returned to the purchaser with transportation charges collect.

Berkeley reserves the right to make changes in design at any time without incurring any obligation to modify equipment previously purchased to conform to subsequent design changes.

BERKELEY DIVISION
BECKMAN INSTRUMENTS, INC.

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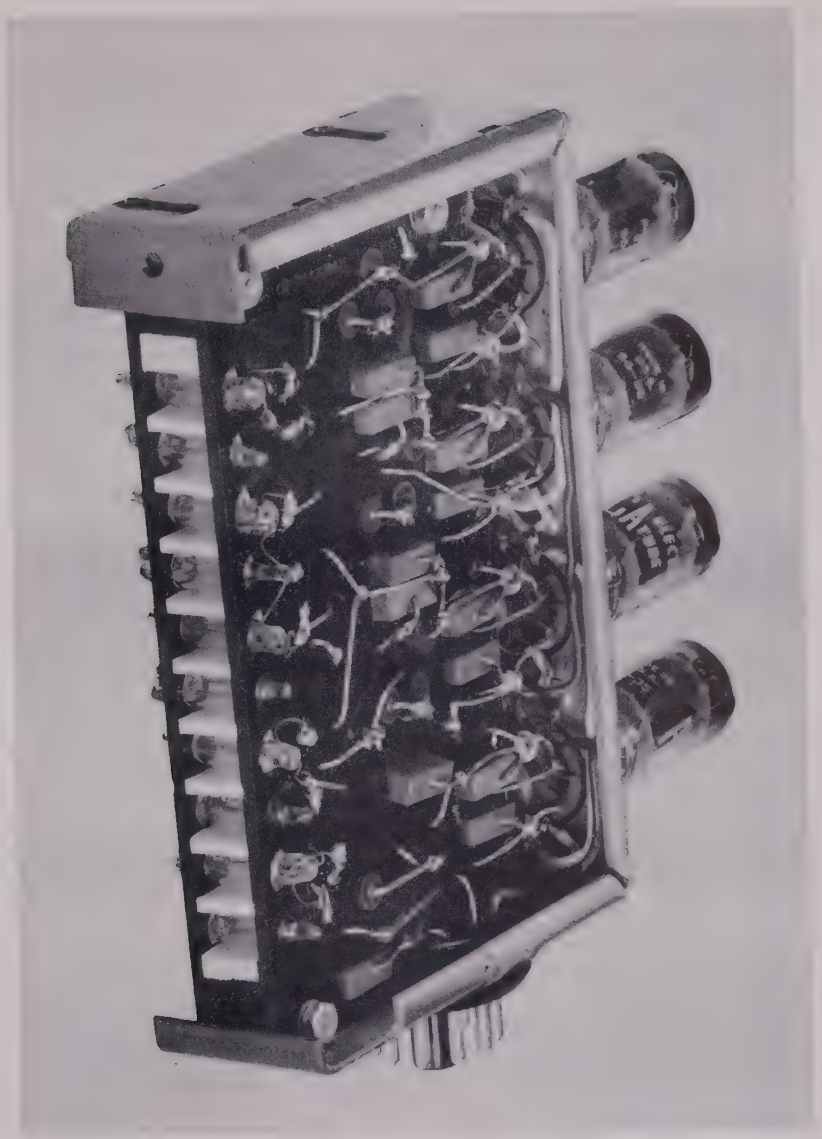

Model 705AH Decimal Counting Unit with side covers and indicating panel removed.

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INTRODUCTION

These decimal counting units are direct-reading, plug-in electronic counters. The number of input pulses received is indicated by the illumination of one of ten neon lamps placed behind a numbered acetate panel. Each unit counts from zero to nine, the tenth pulse resetting the counter to zero and simultaneously generating an output signal. Any number of these units can be connected in cascade (the output of one unit driving the next) forming a counter whose total count capacity depends only on the number of DCU's. Thus, five units will count to 99, 999 resetting to "00, 000" on the 100, 000th pulse.

Models 705AH and 705AK generate a binary coded decimal readout. This code is in the form of high or low voltages at each of four pins on the DCU plug.

SPECIFICATIONS

Count Indication

Direct reading, decimal presentation

Power Requirements

Heaters: 6.3 v. at 1.2 amps

Plates: 300 v. at 13 ma

Input Requirements

Negative pulses (See "OPERATION")

Output Characteristics

Designed to drive a Model 705A DCU or any modification thereof (i.e., 705AH, 705AK, etc.)

Resolution of Paired Pulses

5 microseconds

Reset

Will reset to either zero or nine depending on polarity of reset pulse applied.

Maximum Counting Rate

100, 000 counts per second

Construction

Plug-in unit, 11-pin socket

OPERATION

Power Requirements. The heaters require 6.3 volts ac at 1.2 amperes. The plate circuits may be operated on from 200 to 400 volts, although the design center is 300 volts at 13 ma. Plate voltage may be applied in the form of B + and B - voltages. The d-c level of all output voltages will depend upon the level of the plate supply voltages.

Input Requirements. A negative pulse at least two microseconds wide is required to drive the unit. The optimum pulse amplitude depends on the rise time. With a rise time of 0.5 microseconds (measured between ten and ninety percent values) the pulse amplitude should be between 75 and 135 volts. With a two-microsecond rise time, the amplitude should be between 120 and 165 volts. When operating the plate circuits on 300 volts, optimum performance is obtained with a rise time of one microsecond or less and a pulse amplitude of 100 volts. If the unit is powered by unregulated d-c supplies, the input pulse amplitude should vary in phase with the supply voltage. The input load presented when an input pulse occurs is 15K ohms in series with 100 micromicrofarads.

Output Characteristics. The output is the rectangular waveform shown in Figure 3. As every tenth input pulse triggers the unit from count display "9" to count display "0", a negative transient occurs at pin 4 of the DCU plug. With a plate supply of 300 volts, the potential at pin 4 drops from + 135 to + 55 volts with respect to B-. This transient can be used to drive succeeding decimal counting units or other circuitry. The load impedance connected

between the output terminal and ground must not be less than 300K or 6K in series with 100 micro-microfarads.

Method of Resetting after a Counting Period. A DCU can be reset to a registered count of either zero or nine by the application of a voltage pulse of the proper polarity to the proper pin of the DCU plug. See the table below.

	RESET TO ZERO		RESET TO NINE	
	Pulse Polarity	Applied at Pin No.	Pulse Polarity	Applied at Pin No.
705AH	Neg.	8	Pos.	8
705AJ	Neg.	8	Pos.	8
	Pos.	3	Neg.	3
705AK	Neg.	8	Pos.	8

The reset pin (or pins in the base of Model 705AJ) should be maintained at the B- supply voltage except when a reset pulse occurs. A 50-volt pulse at least 3μseconds wide is adequate. A 100-volt pulse need be only 1.5μseconds wide. There is no maximum pulse width; however the DCU will not begin counting again until the reset pin returns to the B- supply voltage.

Simply disconnecting a reset pin from B- with a switch or relay will have the same effect as applying a positive pulse.

Binary Code Readout. Models 705AH and 705AK generate a modified binary code representing the decimal digit registered. The code appears in the form of a voltage (high or low) at one plate of each of four double-triode binaries. In the table below, "0" represents a plate voltage of approximately +55 volts with respect to B-; "1" represents a plate voltage of about +135 volts with respect to B-. (These are the voltage levels which appear when using a 300-volt plate supply.) Each of the four plates is coupled to a pin of the DCU plug through a 1.2 megohm resistor except in the case of pin 4 on the 705AK DCU. This pin is connected directly to a plate of the fourth binary. To obtain a readout voltage at this pin, it is necessary to add a 1.2M resistor externally.

DECIMAL DIGIT REGISTERED	FOUR - LINE BINARY CODE			
	1st Binary Stage (Pin 2 of DCU plug)	2nd Binary Stage (pin 6 of DCU plug)	3rd Binary Stage (Pin 9 of DCU plug)	4th Binary (Pin 10, 705AH) (Pin 4, 705AK)
0	0	0	0	0
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	0	1	1	0
5	1	1	1	0
6	0	0	1	1
7	1	0	1	1
8	0	1	1	1
9	1	1	1	1

Extinguishing the Indicating Lamps During the Counting Period. On Models 705AJ and 705AK, it is possible to prevent the neon bulbs from lighting by placing approximately -100 volts with respect to B- on pin 10 of the DCU plug. Ordinarily, the user will wish to extinguish the bulb while the DCU is actively counting, and to allow them to light, indicating the registered count at the end of a counting period.

CIRCUIT DESCRIPTION

The Binaries. The decimal counting units contain four "flip-flop" circuits. These circuits are slightly modified versions of the Eccles-Jordan trigger circuit. They are referred to here as binaries.

Figure 1 is a schematic diagram of a typical binary. It consists of two triode voltage amplifiers with the plate of each direct-coupled to the grid of the other. With no input this circuit assumes one of two stable states: V1 conducting steadily and V2 cut

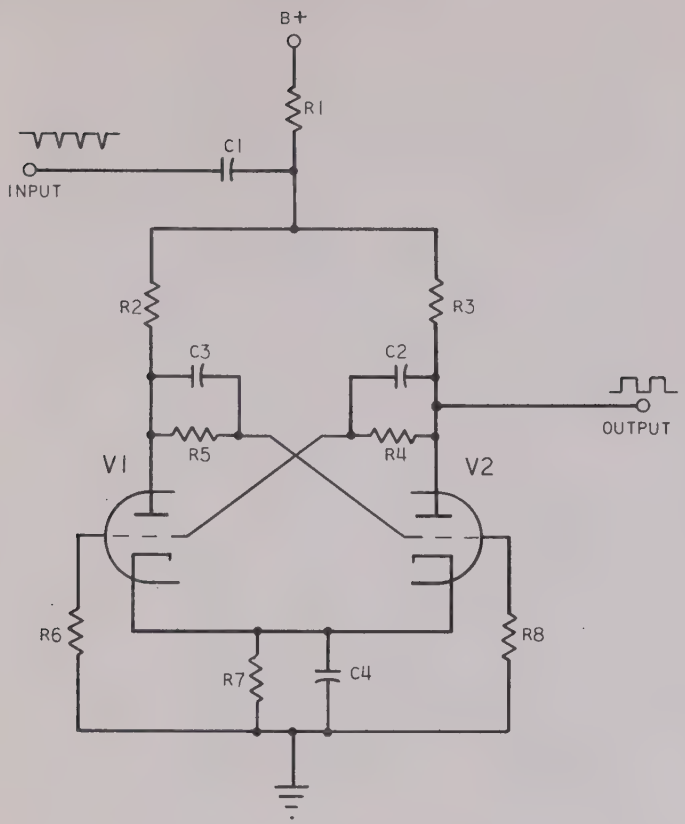


FIGURE 1. A TYPICAL BINARY.

off, or V2 conducting and V1 cut off. Suppose V1 is not conducting. Then, its plate is near the B- voltage. A portion of this voltage, applied to the grid of V2 through the voltage dividing network R5 and R8, raises this grid above cut-off and permits V2 to conduct. While V2 is conducting, the low positive potential at its plate, coupled to the grid of V1 through the dividing network R4 and R6, holds this grid several volts below cut-off. Since small changes in the potential at the grid of V1 will not raise it above cut-off, this state is stable and will persist until disturbed by an appreciable input signal. Notice that, since the circuit is symmetrical, the opposite state is equally stable.

The circuit is triggered from one state to another by negative pulses applied at the input. For example, assume that V2 is conducting and V1 is cut off. If a negative pulse is applied to the input, there is a drop in the plate voltage of V1. This drop in voltage is transmitted through a crossover network (R5, R8, C3 and the grid-to-ground capacitance of V2) and applied to the grid of V2. The plate voltage of V2 then starts to rise, carrying with it the grid of V1. If the input pulse is of sufficient amplitude, V1 begins to conduct. The moment V1 conducts, the drop in voltage at its plate, coupled to the grid of V1, reinforces the negative transient there. This regenerative action proceeds rapidly until V2 is cut off and V1 is conducting at a steady rate. The next adequate input transient causes a reverse action and returns the binary to its original state. Thus, the binary completes a cycle for every two input transients applied, making it a scale-of-two. The output is the drop in voltage at one of the plates as that triode begins to conduct. This output, consisting of one negative transient for every two input transients, is suitable for driving another binary. By connecting binaries in cascade (output of one to input of the next) a counter having a scale of any power of two can be built.

The Scale of Ten. In the Model 705A four binaries are connected in cascade forming a scale-of-16 which is permuted to a scale-of-10 by two positive feedback paths. (See Figures 2 and 3) For the first three negative input pulses, the unit operates like a simple binary counter. At the fourth input pulse, the third binary is triggered for the first time, sending a pulse through the first feedback path which triggers the second binary. Since it requires two input pulses to trigger the second binary, this is equivalent to adding two input pulses; therefore, the state of the unit now

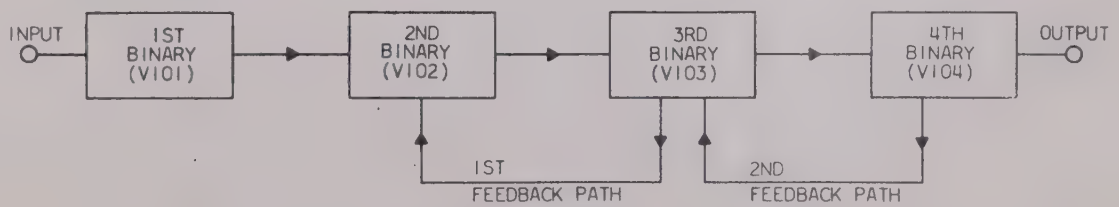


FIGURE 2. BLOCK DIAGRAM.

corresponds to a binary count of six. The sixth input pulse (equivalent to the eight in a simple binary chain) triggers the fourth binary which sends a pulse through the second feedback path, triggering the third binary. This is equivalent to adding four more input pulses so the state of the unit now corresponds to a binary count of 12. For the next four input pulses (7 thru 10) the unit operates again as a simple binary chain, producing an output pulse at the tenth input pulse. Adding the equivalent of six input pulses internally has changed the binary chain from a scale-of-16 to a scale-of-10.

When the third binary is triggered by a feedback pulse, it tends to retrigger the second binary in the same way that it did at the time of input pulse four. This tendency is offset by a simultaneous opposing signal from the fourth binary.

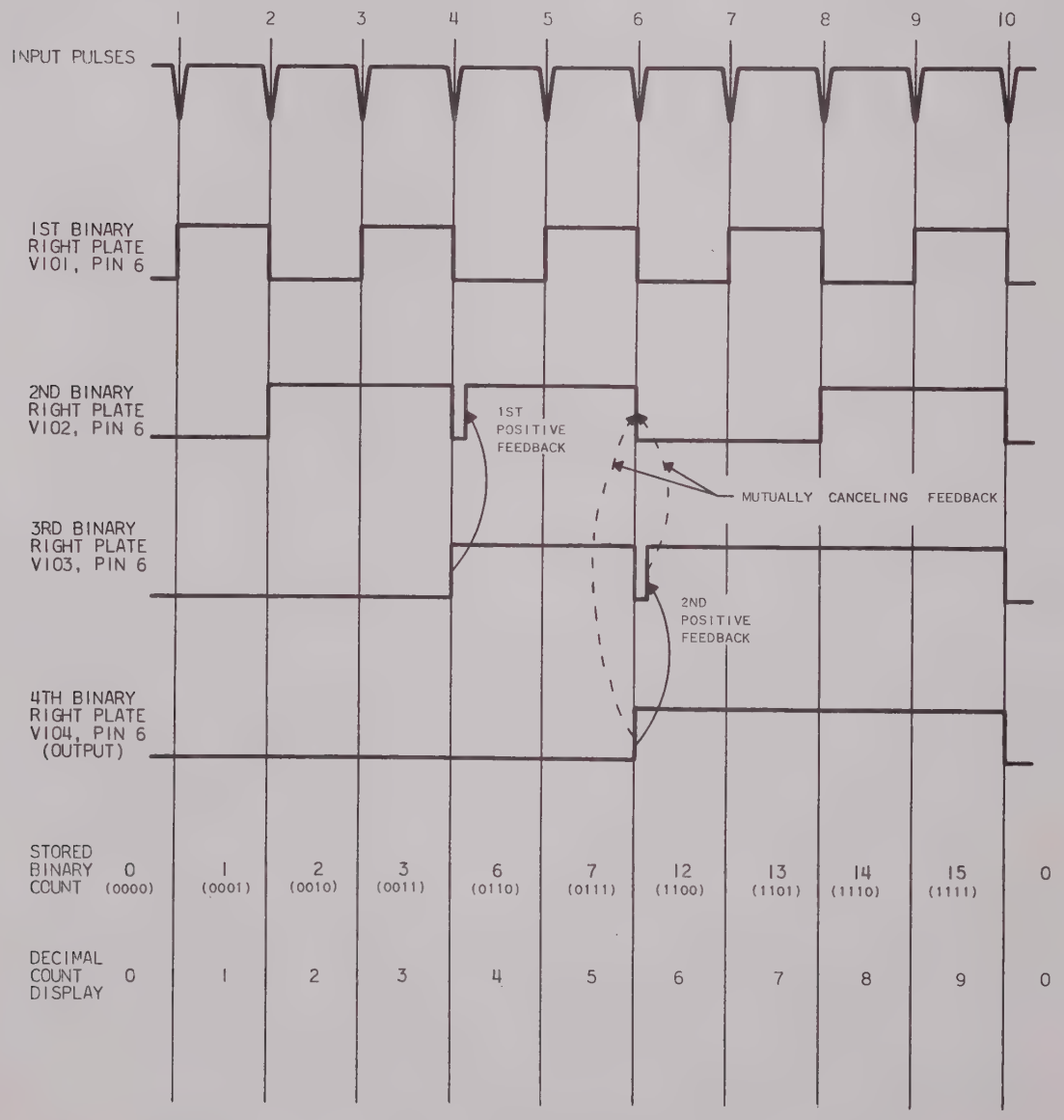


FIGURE 3. IDEALIZED WAVEFORMS. "RIGHT PLATE" REFERS TO THE PLATE APPEARING ON THE RIGHT-HAND SIDE OF THE BINARY AS DRAWN ON THE SCHEMATIC.

TROUBLESHOOTING PROCEDURES

When a decimal counting unit is suspected of counting incorrectly, it should be interchanged with another unit in the instrument or replaced with a spare unit to determine whether the trouble is in the suspected unit or in the associated circuitry. This test should be made very carefully. Because the counting unit is usually the indicating device of an instrument, it is often accused of operating incorrectly when the fault is external to it.

Two methods are recommended for locating a defect in a DCU. The first is to observe the lighting sequence while driving the unit at a slow pulse rate. The second is to study the output waveform of each binary while driving the unit fast enough to create an oscilloscope display. It is impossible to say which method should be used in every case, since marginal failures may occur at high counting speeds and not at lower counting rates, and vice versa. The first method is the only way that a neon lamp failure can be located, and it can be used to locate component and tube failures. For this reason, it is recommended that this method be used first. The table of common troubles lists the probable defects indicated by particular variations from the proper lighting sequence. Binary output waveforms may be compared with the idealized waveforms of Figure 3 and the photographs appearing in Figure 4 & 5.

A table of typical voltages and resistances has been provided to help the serviceman locate a defect within one of the binary stages. Values may deviate considerably from those given without causing trouble. The fact that the unit is designed to operate at plate supply voltages ranging from 200 to 400 volts is a rough indication of permissable tolerances.

TROUBLESHOOTING CHART

NOTE: Reset unit to zero before testing for symptoms

SYMPTOMS	POSSIBLE CAUSES
Unit Fails to Count	(a) Insufficient supply voltage. (b) Input signal of insufficient amplitude (c) Input signal of wrong polarity. (d) First stage inoperative.
Unit Counts Spuriously	(a) Extraneous input signals. (b) Pulses received through power supply. (c) External voltages picked up by output lead.
Units Counts Erratically	(a) Input signal too large or small, incorrect rise time. (b) Supply voltage fluctuating too much.
Unit Fails to Reset	(a) Stray counts from reset switch or associated circuitry. (b) Defective component.

Units counts regularly but neon bulbs light in wrong sequence and the pattern of lighting is repeated consistently after a definite number of input pulses. One or more bulbs may be lit simultaneously during a cycle but the number of states per cycle remains constant.

1. Units skips every other number	(a) First stage defective. (b) Input circuit supplies double pulses.
2. Two stable states per cycle.	(a) Second stage defective(Display sequence may be 01 or 45). (b) Loss of drive to second stage (01).
3. Four stable states per cycle.	(a) Third stage defective (Display sequence may be 0123 or 6789). (b) Loss of drive to third stage (0123).
4. Six stable states per cycle.	(a) Output excessively loaded (Display sequence may be 012345). (b) Last stage inoperative (Display sequence may be 012345 or $67^{89}_{23}89$*). (c) Loss of drive to fourth stage (Display sequence may be 012345).
5. Eight stable states per cycle or any failure where two successive numbers are skipped.	(a) Second or third stage failure.
6. Ten stable states per cycle, but the lighting sequence is incorrect.	(a) When the wrong neon lamp lights, the trouble is usually a defect in the lamp that should have lit, but it may be a defect in the lamp that lit improperly. It's also possible that more than one lamp will light in place of the correct one.
7. Twelve stable states per cycle.	(a) When lighting sequence is $0123^{01}_{45}456789$* the cause may be a failure of the first feedback or lowered cathode emission in first or second binary. (b) When the lighting sequence is $01234567^{23}_{89}89$ the cause may be failure of the second feedback or low cathode emission in third or fourth binary.

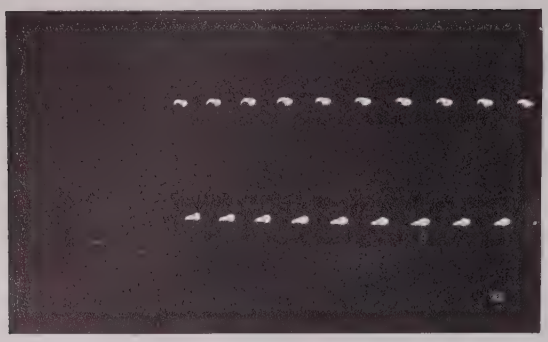
* One digit above another means both lamps are lit.

TABLE OF VOLTAGES & RESISTANCES

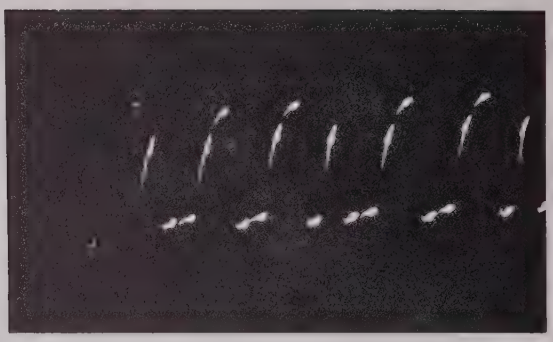
Tube	Pin No.	D-C Voltage with respect to B-.*	Resistance to B minus Terminal**
V101	1	170	105K
	2	17	85K
	3, 8	37	12K
	4, 5, 9	Filaments	
	6	60	105K
	7	37	85K
V102	1	135	93K
	2	15	83K
	3, 8	30	12K
	4, 5, 9	Filaments	
	6	55	93K
	7	30	83K
V103	1	135	100K
	2	15	83K
	3, 8	30	12K
	4, 5, 9	Filaments	
	6	55	100K
	7	30	83K
V104	1	135	93K
	2	15	83K
	3, 8	30	12K
	4, 5, 9	Filaments	
	6	55	93K
	7	30	83K

* Voltages measured in unit with 300-volt plate supply

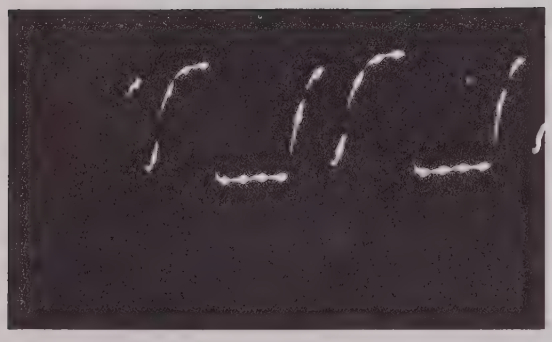
** Before making resistance measurements jumper pins 3 and 8 on the DCU plug.



(1) First Binary Output (V101, Pin 6).
Upper voltage level is +168v
Lower voltage level is +55v



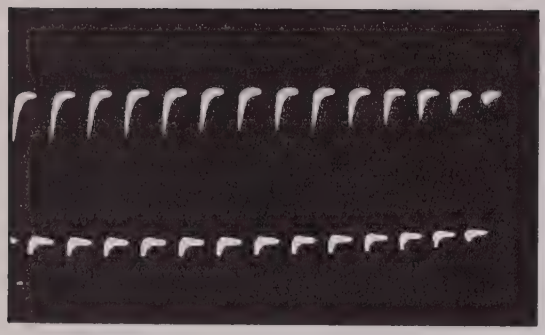
(2) Second Binary Output (V102, Pin 6)
Upper voltage level is +140v
Lower voltage level is +55v.



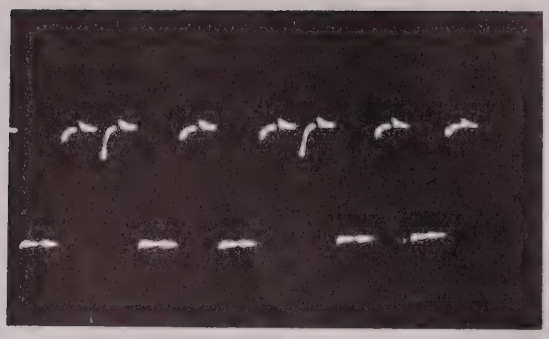
(3) Third Binary Output (V103, Pin 6)
Upper voltage level is +140v.
Lower voltage level is +55v.

(4) Fourth Binary Output (V104, Pin 6).
Upper voltage level is +140v.
Lower voltage level is +55v.

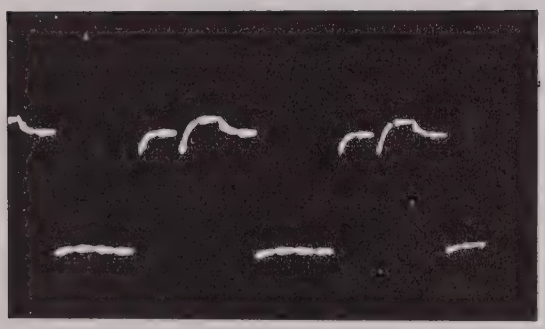
FIGURE 4. BLANKED WAVEFORMS AT INPUT FREQUENCY OF 20KC. ALL VOLTAGE LEVELS ARE MEASURED WITH RESPECT TO B MINUS.



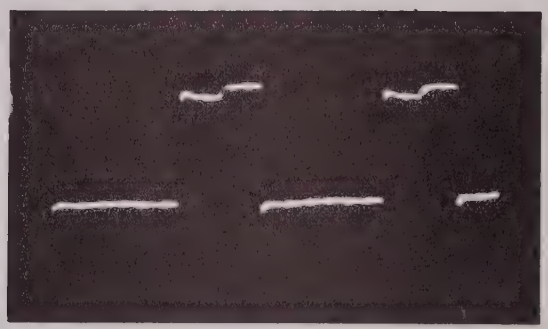
(1) First Binary Output (V101, Pin 6).
Upper Voltage level is +168V
Lower voltage level is +55v



(2) Second Binary Output (V102, Pin 6)
Upper voltage level is +140v
Lower voltage level is +55v.



(3) Third Binary Output (V103, Pin 6)
Upper voltage level is +140v.
Lower voltage level is +55v



(4) Fourth Binary Output (V104, Pin 6).
Upper voltage level is +140v.
Lower voltage level is +55v.

FIGURE 5. BLANKED WAVEFORMS AT INPUT FREQUENCY OF 100KC. ALL VOLTAGE LEVELS ARE MEASURED WITH RESPECT TO B MINUS.

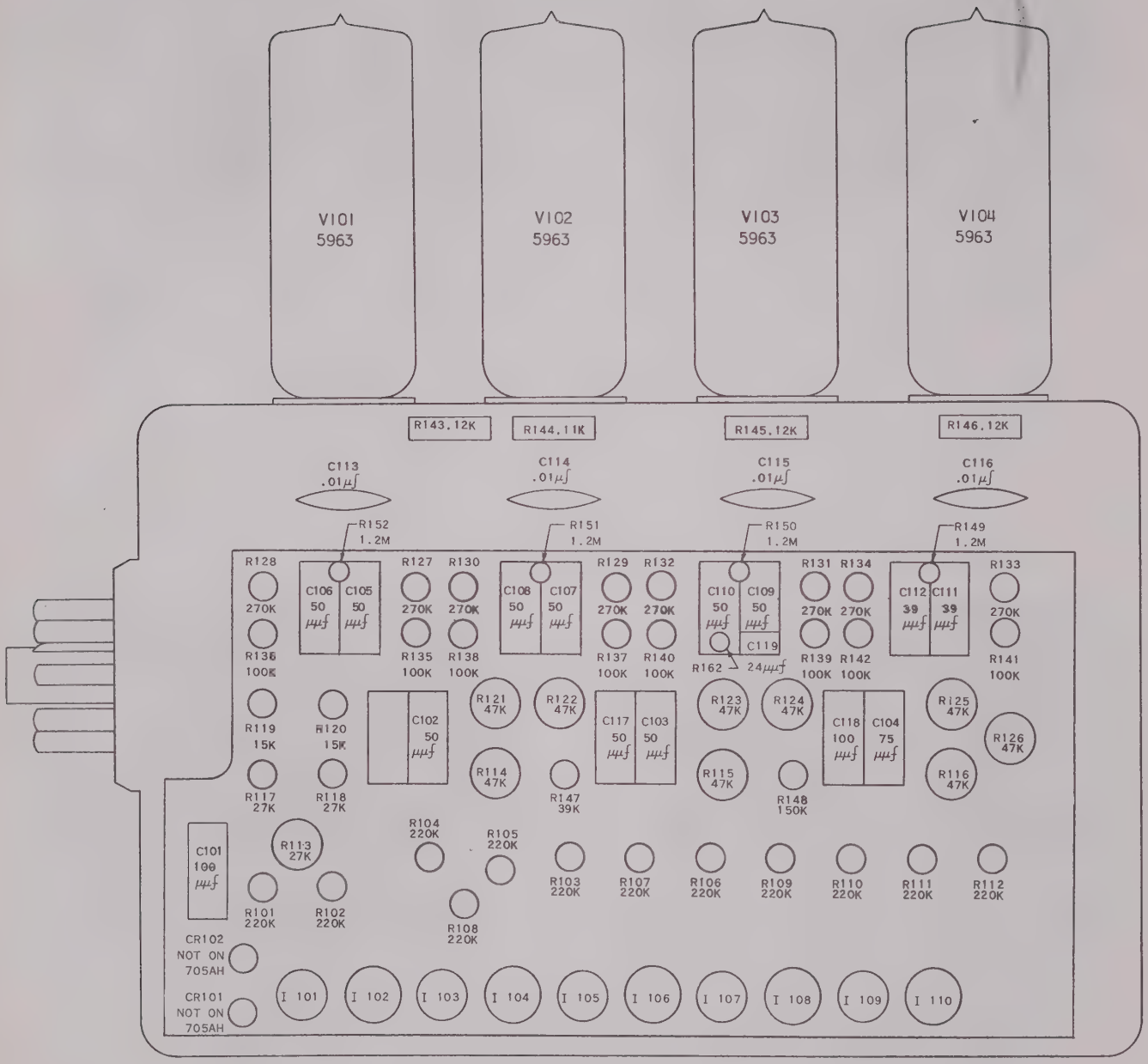
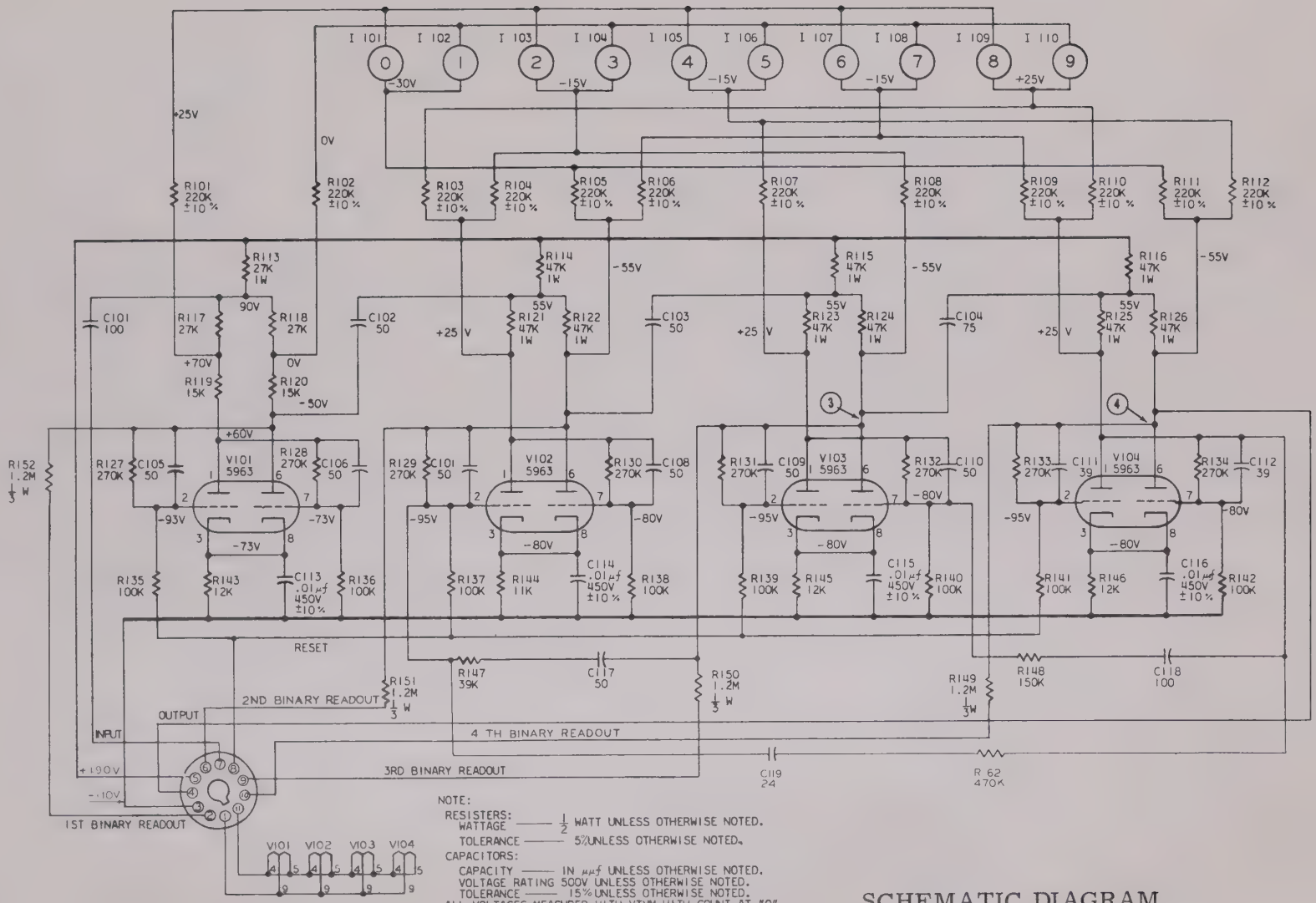
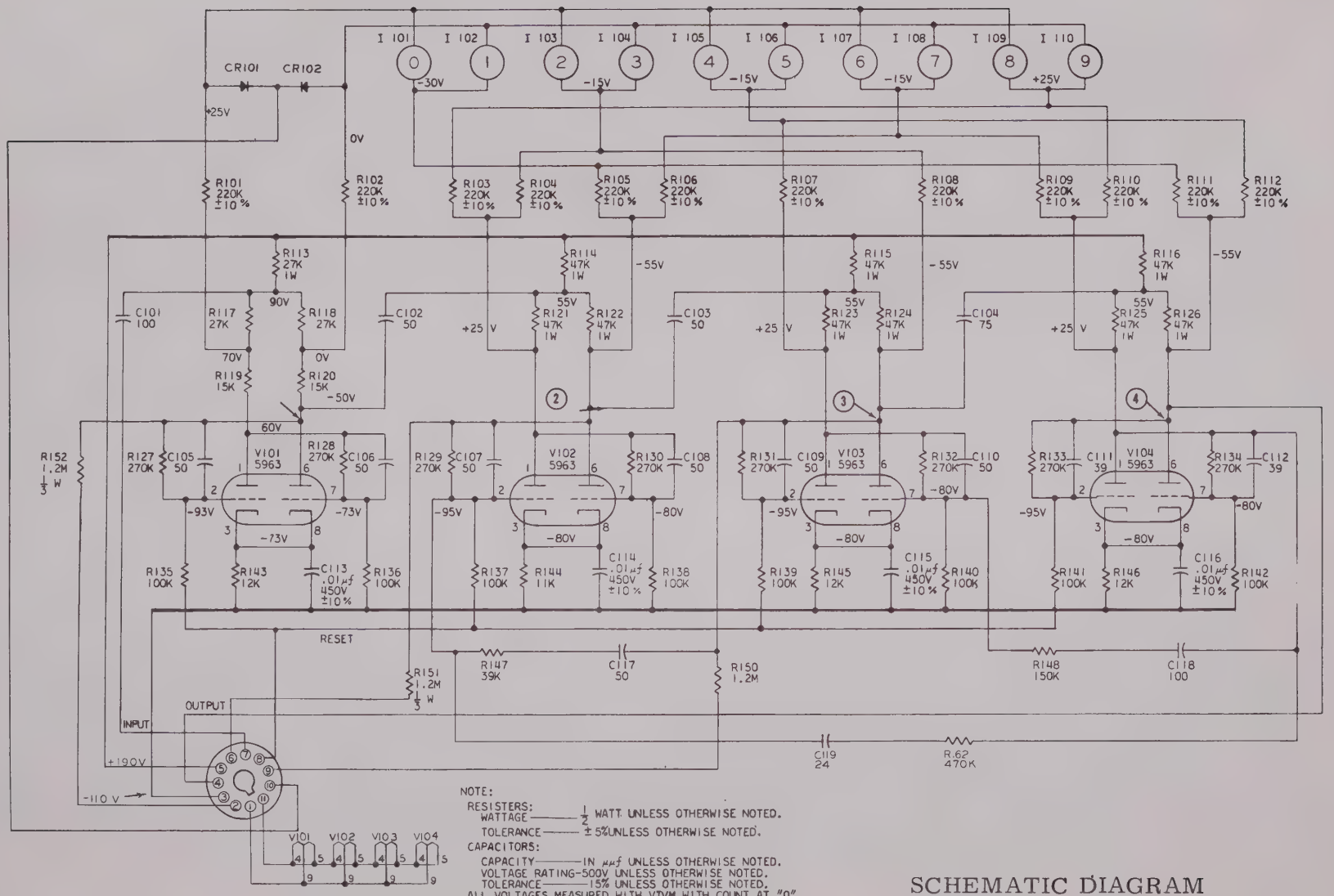


FIGURE 6. PARTS LOCATION

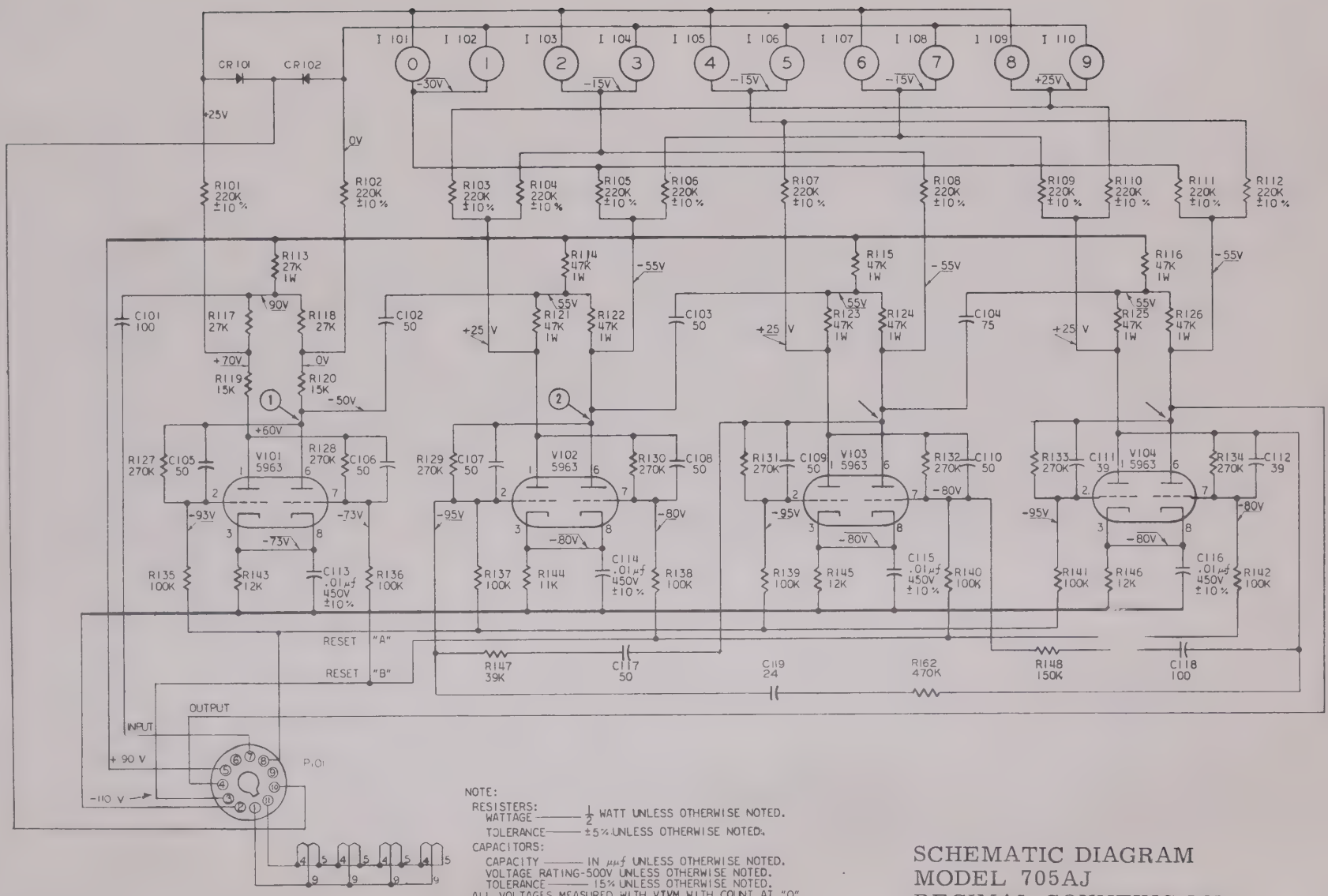


SCHEMATIC DIAGRAM
MODEL 705AH
DECIMAL COUNTING UNIT



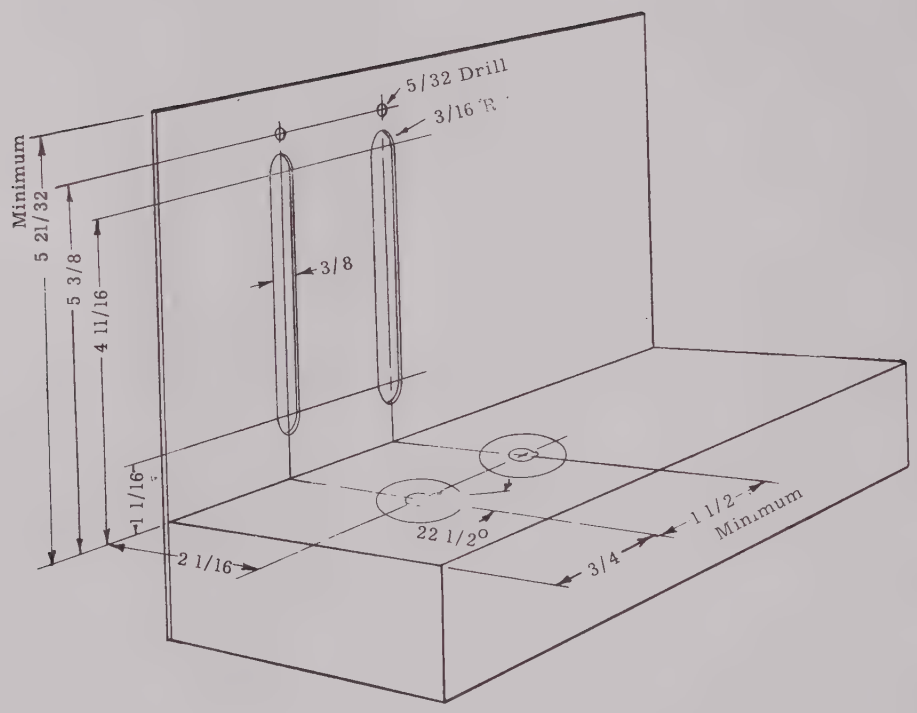
NOTE:
RESISTERS:
WATTAGE——— ½ WATT UNLESS OTHERWISE NOTED.
TOLERANCE——— ±5% UNLESS OTHERWISE NOTED.
CAPACITORS:
CAPACITY———IN μμf UNLESS OTHERWISE NOTED.
VOLTAGE RATING-500V UNLESS OTHERWISE NOTED.
TOLERANCE———15% UNLESS OTHERWISE NOTED.
ALL VOLTAGES MEASURED WITH VTVM WITH COUNT AT "0".

SCHEMATIC DIAGRAM
MODEL 705AK
DECIMAL COUNTING UNIT



NOTE:
RESISTERS:
WATTAGE ——— $\frac{1}{2}$ WATT UNLESS OTHERWISE NOTED.
TOLERANCE ——— ±5% UNLESS OTHERWISE NOTED.
CAPACITORS:
CAPACITY ——— IN μμf UNLESS OTHERWISE NOTED.
VOLTAGE RATING-500V UNLESS OTHERWISE NOTED.
TOLERANCE ——— 15% UNLESS OTHERWISE NOTED.
ALL VOLTAGES MEASURED WITH VTVM WITH COUNT AT "0".
AND PIN #10 DISCONNECTED.

SCHEMATIC DIAGRAM
MODEL 705AJ
DECIMAL COUNTING UNIT



NOTE: Dimensions are based on the use of an Amphenol "MIP" 8 or 11-pin socket mounted above the chassis.

The drawing shows chassis dimensions for mounting two Model 705A DCU's side by side. All modifications of the Model 705A (705AH, 705AF, etc.) have precisely the same dimensions as the standard 705A.

Mounting Dimensions, Model 705A and All Modifications Thereof

INSTRUCTION MANUAL

MODELS 707AH & 707AK
DECIMAL COUNTING UNITS

LOT NO. _____

BERKELEY division of
Beckman Instruments Inc.

April 11 1957
Richmond, California

WARRANTY

Instruments sold by Berkeley Division, Beckman Instruments, Inc., (hereafter called "the Company") are warranted only as stated below.

Subject to the exceptions and upon the conditions specified below, the Company agrees to correct, either by repair, or, at its election, by replacement, any defect of material or workmanship which develops within one year after delivery of the instrument to the original purchaser by the Company or by an authorized representative, provided that investigation and factory inspection by the Company discloses that such defect developed under normal and proper use.

The exceptions and conditions mentioned above are the following:

(a) All instruments claimed defective must be returned to the Company, transportation charges prepaid, and will be returned to the customer with the transportation charges collect.

(b) The Company makes no warranty concerning components or accessories not manufactured by it, such as tubes, fuses, batteries, etc. However, in the event of the failure of any component or accessory not manufactured by the Company, the Company will give reasonable assistance to the purchaser in obtaining from the respective manufacturer whatever adjustment is reasonable in the light of the manufacturer's own warranty.

(c) The Company shall be released from all obligations under its warranty in the event repairs or modifications are made by persons other than its own service personnel or authorized representatives' personnel unless such repairs by others are made with the written consent of the Company.

(d) Except as stated above, the Company makes no warranty, express or implied (either in fact or by operation of law), statutory or otherwise; and, except to the extent stated above, the Company shall have no liability under any warranty, express or implied (either in fact or by operation of law), statutory or otherwise.

(e) The Company expressly disclaims any liability to its customers, dealers, and to users of its products, and to any other person or persons for consequential damages of any kind and from any cause whatsoever arising out of or in any way connected with the manufacture, sale, repair, replacement of, or arising out of or in any way connected with the use of any of its products.

(f) Representations and warranties made by any person, including representatives of the Company, which are inconsistent or in conflict with the terms of this warranty (including but not limited to the limitation of the liability of the Company as set forth above) shall not be binding upon the Company unless reduced to writing and approved by an officer of the Company.

(g) This warranty shall be governed by the laws of the State of California.

Claims for damage in shipment should be filed promptly with the transportation company.

All correspondence concerning the instrument should specify the model and serial number. This information appears on the company name plate. Any inquiry concerning details of operation, possible modifications, etc., should be addressed to the Sales Department, Berkeley division of Beckman Instruments, Inc., Richmond 4, California.

REPAIR SERVICE

Experienced service personnel and special test equipment are available at the factory to perform any necessary repairs. Every effort will be made to expedite the repair of instruments returned for servicing. Repair work will be performed only upon receipt of a written purchase order or authorization. Instruments to be repaired should be addressed to SERVICE AND REPAIR DEPARTMENT with transportation charges prepaid. Repaired instruments will be returned to the purchaser with transportation charges collect.

Berkeley reserves the right to make changes in design at any time without incurring any obligation to modify equipment previously purchased to conform to subsequent design changes.

BERKELEY DIVISION
BECKMAN INSTRUMENTS, INC.

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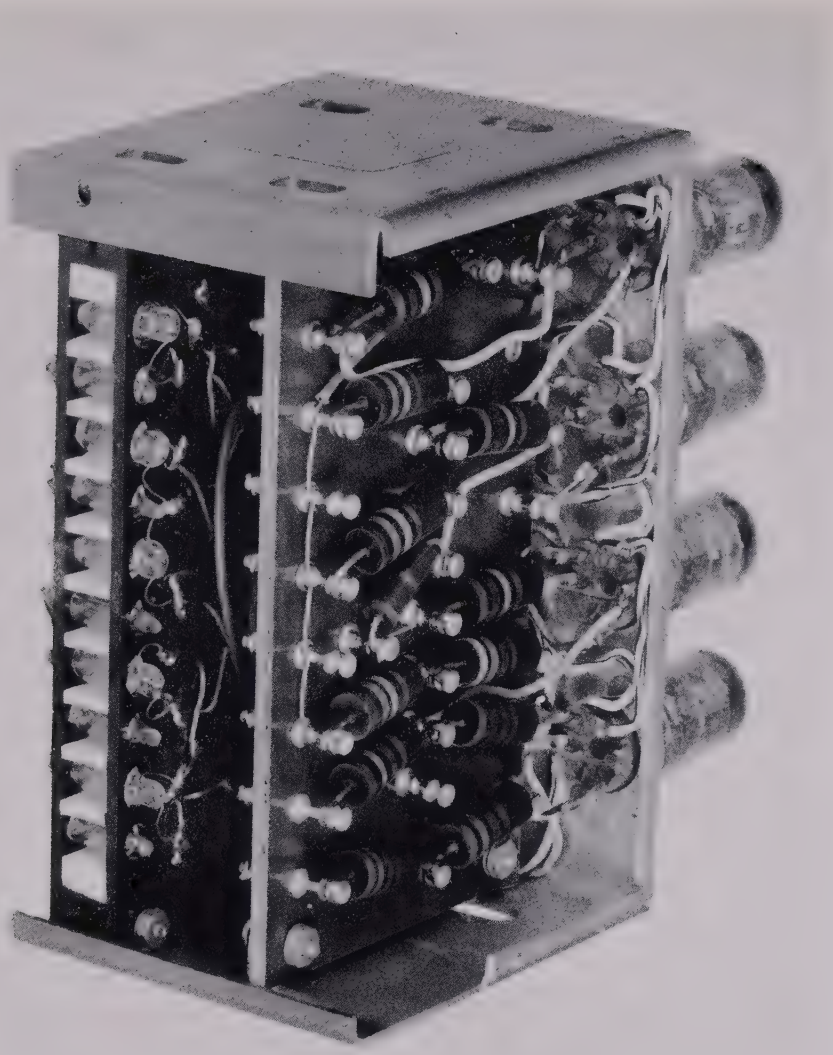
Berkeley division BECKMAN INSTRUMENTS INC.



Model 707AH Decimal Counting Unit with
side covers and indicating panel removed.

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Schematic Diagram, Model 707AH, Dwg. No. 707D200

Schematic Diagram, Model 707AK, Dwg. No. 707D500

GENERAL DESCRIPTION

Models 707AH and 707AK are direct-reading, plug-in decimal counting units. The units are nearly identical except that the Model 707AK has added facilities for extinguishing the indicating lamps. Except when noted otherwise, all the information in the manual applies to both models.

A decimal counting unit registers voltage pulses applied at an input. Starting from zero it counts to nine, returning to zero on the tenth pulse and simultaneously generating an output signal. The count score is indicated by the illumination of one of ten neon lights placed behind a numbered acetate panel. This unit will count at a maximum rate of 1,000,000 pulses per second. This output is suitable for driving the Model 705A DCU or any modification thereof (705AH, 705AK, etc.) Decimal counting units may be connected in cascade (output of one to input of next), thus forming a counter whose total capacity depends only on the number of units in the chain. For example, a chain consisting of one 707AH followed by five 705AH's will count to 999,999, returning to "000,-000" on the 1,000,000th input pulse.

The unit also generates a binary-coded decimal readout in the form of high or low voltages at each of four pins on the DCU plug.

SPECIFICATIONS

Count Indication

Illuminated decimal digits

Input Requirements

Negative pulses. (See "OPERATION")

Resolution of Paired Pulses

0.8 μseconds

Maximum Counting Rate

1,000,000 Counts-per-second

Output Characteristics

Designed to drive a Model 705A DCU or any modification thereof. (See "OPERATION".)

Reset

Will reset to either zero or nine depending on polarity of reset pulse applied.

Power Requirements

Heaters: 6.3V a-c at 5.4 amps near ground potential.

Plates: 175 to 260 volts. (Design center is 225 volts at 60 ma.)

Construction

Plug-in unit which fits into standard 11-pin tube socket.

Dimensions

3" by 5-5/8" by 5-3/8"

Weight

1-1/2 pounds.

Tube Complement

Six type 6AL5. Four type 5687.

INSTALLATION AND OPERATION

When purchased as part of another instrument, the decimal counting units are fully installed and ready to function. DCU's purchased separately should be installed and operated in accordance with the directions that follow.

Mounting. Figure 1 shows the dimensions of a chassis suitable for mounting one of these DCU's next to a 705A DCU.

Input Requirements. For best operation the DCU should be driven by a type 6AS6 pentode whose plate is connected only to the input pin of the DCU. With this arrangement the DCU supplies plate voltage for the pentode and the first stage of the DCU becomes the plate load. The control grid of the pentode should be driven by positive pulses which rise from cut-off voltage to zero grid bias within 0.15 μseconds. Pulse width should be between 1.25 and 0.4 μseconds.

Output Characteristics. The output signal is a rectangular waveform generated by the 4th binary stage and appearing at pin 4 of the DCU plug. This waveform is shown in Figure 3. As every tenth pulse triggers the unit from count display "9" to count display "0", a negative transient occurs at pin 4. With a plate supply of 225 volts, the potential at pin 4 drops from +180 volts to +90 volts. This transient can be used to drive another decimal counting unit or other circuitry. The impedance connected between pin 4 and ground must not be less than 100K or 5K in series with 100$\mu\mu$f.

Method of Resetting after a Counting Period. The unit can be reset to a registered count of either zero or nine by applying a pulse to the reset pin (pin 8) of the DCU plug. A negative pulse resets it to zero; a positive pulse to nine. The reset pin should be maintained at ground potential except when a pulse occurs. Necessary pulse amplitude depends upon pulse width: a wide pulse need not be so high as a narrow pulse. A pulse 1 μsecond wide should be at least 25 volts high. With a pulse width of 5 μseconds an amplitude of 15 volts is adequate. There is no maximum pulse width; however, the DCU will not begin counting again until the reset pin returns to ground potential.

Binary Coded Readout. The unit generates a modified binary code representing the decimal digit registered. This code appears in the form of a voltage (high or low) at one plate of each of four double-triode binaries. With one exception noted below, each of the four plates is connected to a pin of the DCU plug through a 1.2M isolating resistor. In the table below, "0" represents a plate voltage of +110 volts or less and "1" represents a plate voltage of +135 volts or more.

DECIMAL DIGIT REGISTERED	FOUR - LINE BINARY CODE			
	1st Binary (Pin 2 of DCU plug)	2nd Binary (Pin 6 of DCU plug)	3rd Binary (Pin 10 of DCU plug)	4th Binary (Pin 9, 707AH Pin 4, 707AK)
0	0	0	0	0
1	1	0	0	0
2	0	1	0	0
3	1	1	0	0
4	0	1	1	0
5	1	1	1	0
6	0	0	1	1
7	1	0	1	1
8	0	1	1	1
9	1	1	1	1

Extinguishing the Indicating Lamps. On Model 707 AK it is possible to prevent the neon bulbs from lighting by placing -100 volts with respect to ground on pin 9 of the DCU plug. Ordinarily, the user will wish to extinguish the bulbs while the DCU is actively counting and to allow them to light, indicating the registered count, at the end of a counting period.

CIRCUIT DESCRIPTION

The Binaries. The DCU contains four "flip-flop" circuits. These circuits are modifications of the well-known Eccles-Jordan trigger circuit. They are referred to here as binaries.

Figure 1 is a schematic diagram of a typical binary. It consists of two triode voltage amplifiers with the plate of each direct-coupled to the grid of the other. With no input this circuit assumes one

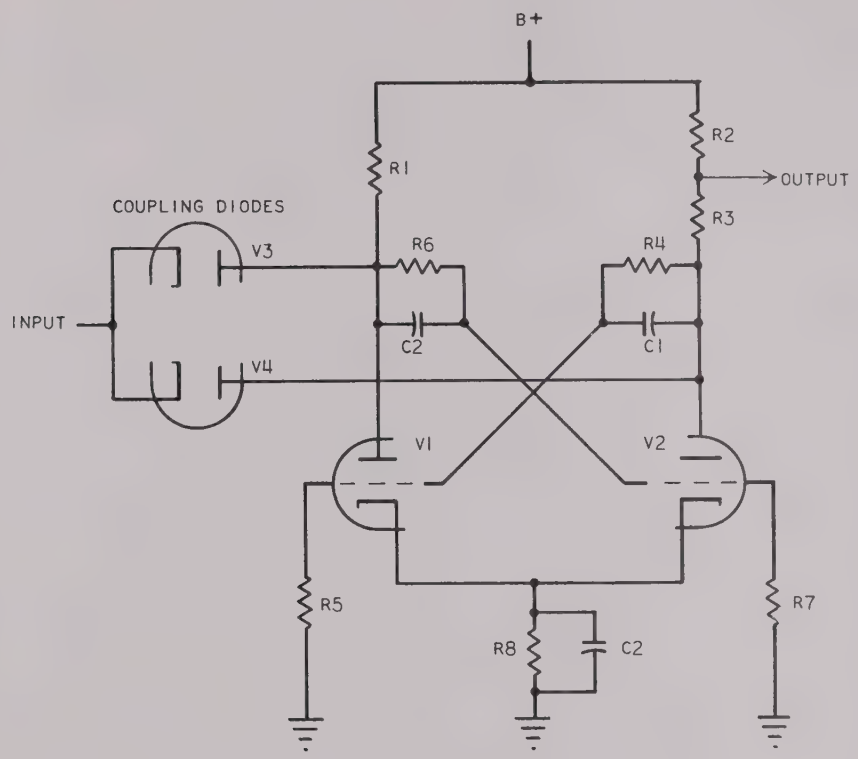


FIGURE 1. A TYPICAL BINARY.

of two stable states: V1 conducting steadily and V2 cut off, or V2 conducting and V1 cut off. Suppose V1 is not conducting. Then, its plate is near the B+ voltage. A portion of this voltage, applied to the grid of V2 through the voltage dividing network R6 and R7, raises this grid above cut-off and permits V2 to conduct. While V2 is conducting, the low positive potential at its plate, coupled to the grid of V1 through the dividing network R4 and R5, holds this grid several volts below cut-off. Since small changes in the potential at the grid of V1 will not raise it above cut-off, this state is stable and will persist until disturbed by an appreciable input signal. Notice that since the circuit is symmetrical the opposite state is equally stable.

The circuit is triggered from one state to another by negative pulses applied at the input. For example, assume that V2 is conducting and V1 is cut off. If a negative pulse is applied to the input, there is a drop in the plate voltage of V1. This drop in voltage is transmitted through a cross-over network (R6, R7, C2 and the grid-to-ground capacitance of V2) and applied to the grid of V2. The plate voltage of V2 then starts to rise, carrying with it the grid of V1. If the input pulse is of sufficient amplitude, V1 begins to conduct. The moment V1 conducts, the drop in voltage at its plate, coupled to the grid of V1, re-enforces the negative transient there. This regenerative action proceeds rapidly until V2 is cut-off and V1 is conducting at a

steady rate. The next adequate input transient causes a reverse action and returns the binary to its original state. Thus, the binary completes a cycle for every two negative input transients applied, making it a scale-of-two. The output is the drop in voltage at the junction of the plate load resistors of V2 as that triode begins to conduct. This output, consisting of one negative transient for every two input transients, is suitable for driving another binary. By connecting binaries in cascade (output of one to input of next), a counter having a scale of any power of two can be built.

The Scale of Ten. In the DCU four binaries are connected in cascade forming a scale-of-16 which is permuted to a scale-of-10 by adding the equivalent of six input pulses internally. With this arrangement, the binaries pass through a complete cycle for every 10 rather than for every 16 input pulses. (See figures 2 and 3.) Assuming the unit is reset to a registered count of zero, it operates like a scale-of-16 for the first three input pulses.

When the fourth input pulse occurs, the output pulse of the 1st binary is diverted from the 2nd binary to the 4th binary. This is done by blocking the input to the 2nd binary with a clamping diode at the same time that a by-pass route from the 1st to the 4th binary is open. Since in a scale-of-16 it takes two input pulses to trigger the second binary but eight pulses to trigger the fourth binary, this action is equivalent to adding six input pulses. After the fourth input pulse, the state of the unit corresponds to a registered binary count of 10. For the next six input pulses the unit operates again like a scale-of-16, returning to a registered count of zero on the tenth pulse.

Figure 3 shows how the voltages throughout the unit change as successive input pulses occur. A voltage level lower than +120 volts corresponds to a binary digit "0". A level higher than +120 volts corresponds to a binary digit "1". Each negative transient drives the next binary except in the case of the first binary output transient which occurs at the fourth input pulse. This transient drives the fourth binary instead.

The clamping voltages are developed at the junction of plate load resistors in the output triodes of the second and fourth binaries. When the output plate of one of these binaries is in its low voltage state, the plate of the injection diode to which it is coupled through a clamping diode is held at a voltage low enough to block any negative transient at the cathode.

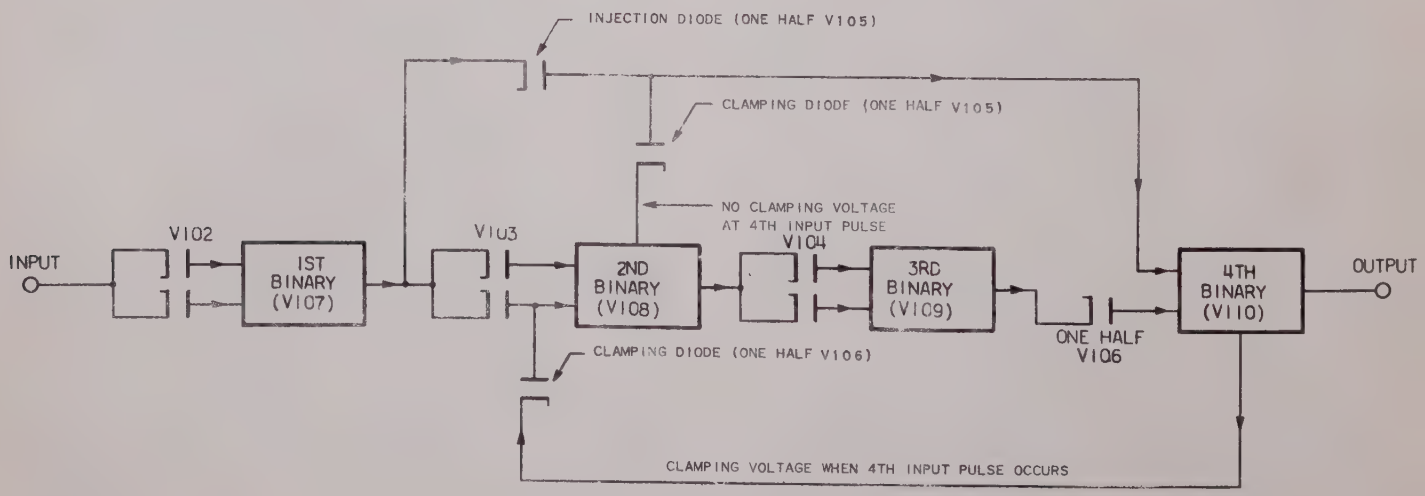


FIGURE 2. FUNCTIONAL DIAGRAM.

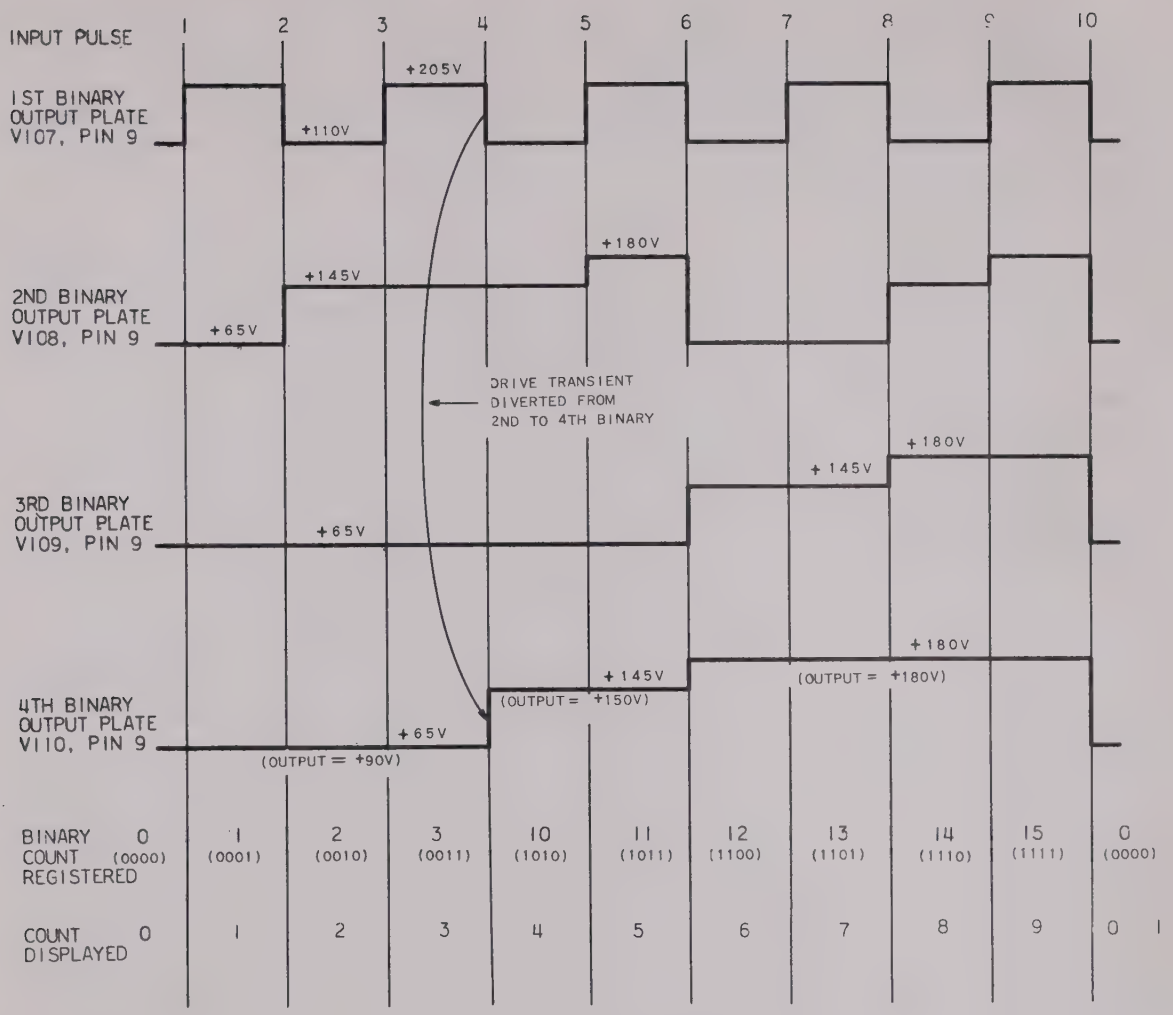


FIGURE 3. IDEALIZED WAVEFORMS.

TROUBLESHOOTING PROCEDURES

When a decimal counting unit is suspected of counting incorrectly, it should be replaced with a spare unit to determine whether the trouble is in the suspected unit or in the associated circuitry. This test should be made very carefully. The counting unit is usually the indicating device of an instrument, and is quite often accused of operating incorrectly when the fault is external to it.

Two methods are recommended for locating a defect in a DCU. The first is to observe the lighting sequence while driving the unit at a slow pulse rate. The second is to study the output waveform of each binary while driving the unit fast enough to create an oscilloscope display. It is impossible to say which method should be used in every case, since marginal failures may occur at high counting speeds and not at lower counting rates, and vice versa. The first method is the only way that a neon lamp failure can be located, and it can be used to locate component and tube failures. For this reason, it is recommended that this method be used first. The table of common troubles lists the probable defects indicated by particular variations from the proper lighting sequence. Binary output waveforms may be compared with the idealized waveforms of Figure 3 and the photographs appearing in Figure 4.

A table of typical voltages and resistances has been provided to help the serviceman locate a defect within one of the binary stages. Values may deviate considerably from those given without causing trouble. The fact that the unit is designed to operate at plate supply voltages ranging from 175 to 260 volts is a rough indication of permissable tolerances.

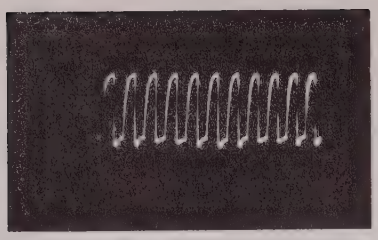
TROUBLESHOOTING CHART

NOTE: Reset unit to zero before testing for symptoms. Reset can be accomplished by momentarily applying -50VDC to reset pin.

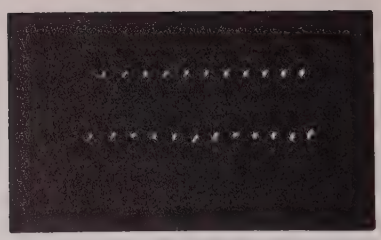
SYMPTOMS	POSSIBLE CAUSES
Unit fails to count	(a) Insufficient supply voltage. (b) Input signal of insufficient amplitude. (c) Input signal of wrong polarity (d) First stage inoperative (V107).
Units counts spuriously	(a) Stray input signal. (b) Pulses received through power supply. (c) External voltages picked up by output lead.
Units count erratically	(a) Input signal too large or small, incorrect rise time. (b) Supply voltage fluctuating too much.
Unit fails to reset	(a) Stray counts from reset switch or associated circuitry. (b) Defective component
Units counts regularly but neon bulbs light in wrong sequence and the pattern of lighting is repeated consistently after a definite number of input pulses. One or more bulbs may be lit simultaneously during a cycle but the number of states per cycle remains constant.	
1. Unit skips every other number	(a) First stage defective (V107). (b) Input circuit supplies double pulses.
2. Two stable states per cycle	
(a) Unit resets to 2. The first display cycle is 2345 and subsequent cycles are 45	Second binary (V108) defective.
(b) Units resets to 0. Display cycle is 01	Second binary (V108) or injection diode V103 defective.

	(c) Unit resets to 0. The first display cycle after reset is 0123 and subsequent cycles are 23.	Fourth binary (V110) or injection diode V105 defective.
	(d) Unit resets to 0. The first display cycle is 012345 and subsequent cycles are 45.	Injection diode V103 defective.
3.	Four stable states per cycle. Two lamps may be lit during some of these states.	
	(a) Resets to 6. Display cycle is 6789.	Third binary (V109) defective.
	(b) Resets to $\frac{0}{4}$. Display cycle is $\frac{01}{45}45$.*	Third binary (V109) defective.
	(c) Resets to 0. First display cycle after reset is 012345; subsequent cycles are $\frac{0}{4}145$*.	Injection diode in V104 defective.
	(c) Resets to 0. First display cycle after reset is 0123456789; subsequent cycles are 6789.	Injection diode in V104 defective.
4.	Eight stable states per cycle. Two lamps may be lit during some of these states.	
	(a) Resets to 0 but lamp 4 is lit also while reset pin is at -50VDC. Display cycle is $\frac{01}{45}456789$.	Fourth binary (V110) defective.
	(b) Resets to 0. Display cycle is 01456789.	Diode in V105 defective.
	(c) Resets to 0. Display cycle is 01236789.	Diode in V106 defective.
	(d) Resets to 0. First cycle after reset is 0123456789; subsequent cycles are $\frac{01}{45}456789$.	Diode in V106 defective.
5.	More than ten stable states per cycle as observed on an oscilloscope.	(a) Input pulse amplitude too small. (b) Marginal tube in any stage.
6.	Unit scales correctly as observed on an oscilloscope, but lighting pattern is 13579 at a slow repetition rate. No lamp lights on reset.	(a) V101 defective.
7.	Unit scales correctly as observed on an oscilloscope but lighting pattern is 02468 at high frequency and at a slow repetition rate. Resets to 0.	(a) V101 defective.

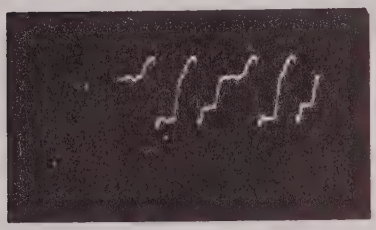
* One digit above another means both lamps are lit.



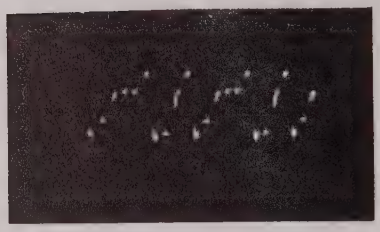
(1) First stage (Pin 9, V107) peaks at +205v and +110v.



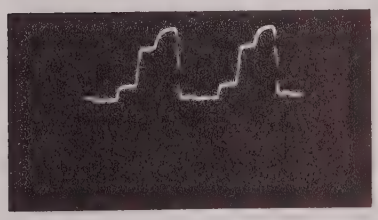
Same waveform blanked at each input pulse.



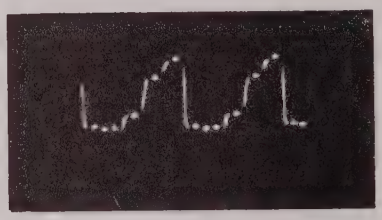
(2) Second stage (Pin 9, V108) peaks at +180v and +65v. Step at +145v.



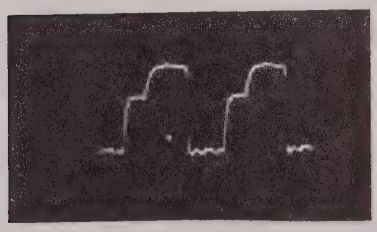
Same waveform blanked at each input pulse.



(3) Third stage (Pin 9, V109) peaks at +180v and +65v.



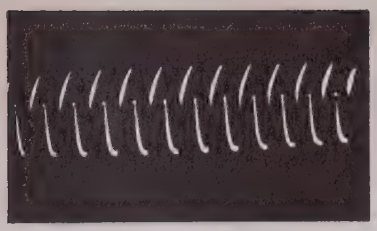
Same waveform blanked at each input pulse.



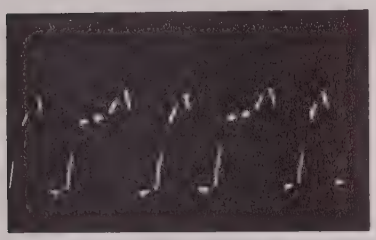
(4) Fourth stage, Pin 9, V110, UVL +180, LVL +65, step at +145, frequency 500Kc.

Same waveform blanked at each input pulse.

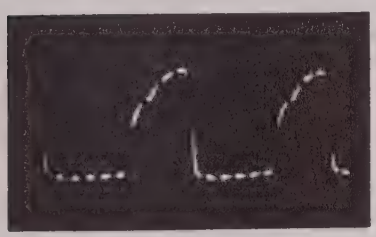
FIGURE 4. TYPICAL WAVEFORMS WITH 500KCS INPUT FREQUENCY.



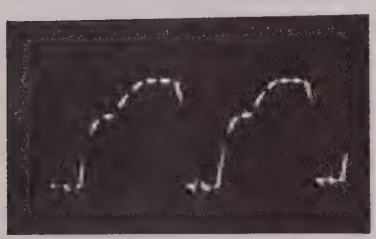
(1) First stage, (Pin 9, V107). Peaks at +190v +105v.



(2) Second stage (Pin 9, V108). Peaks at +180v and +65v. Step at +145v.

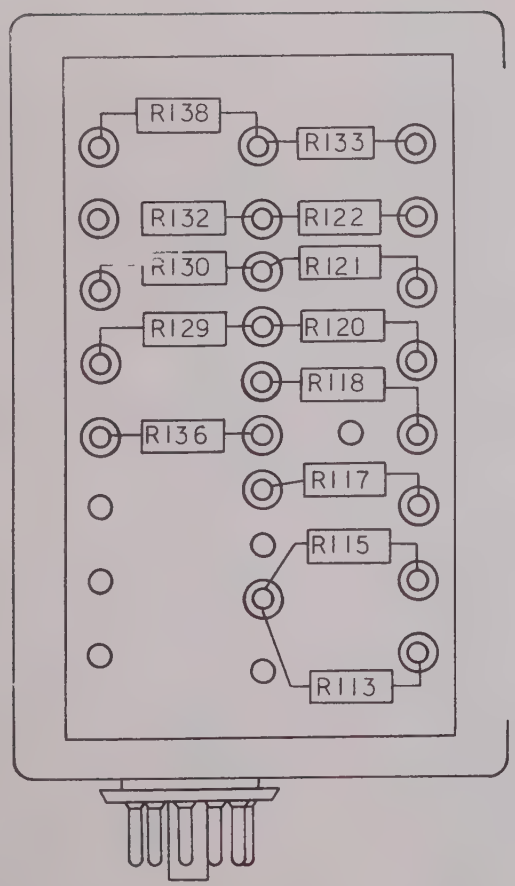


(3) Third stage (Pin 9, V109). Peaks at +180v and +65v.

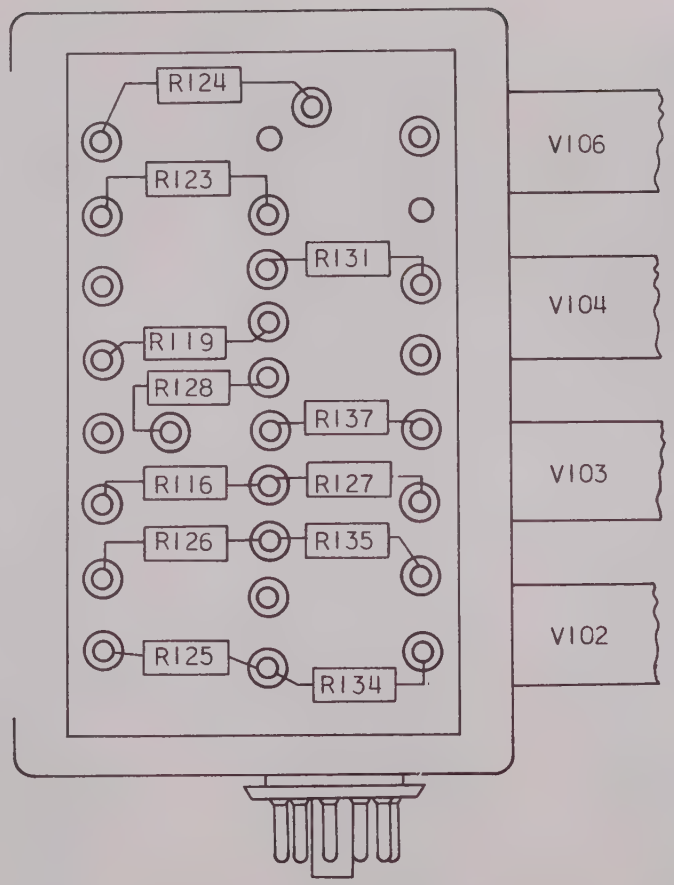


(4) Fourth stage (Pin 9, V110). Peaks at +180v and +65v. Step at +145v.

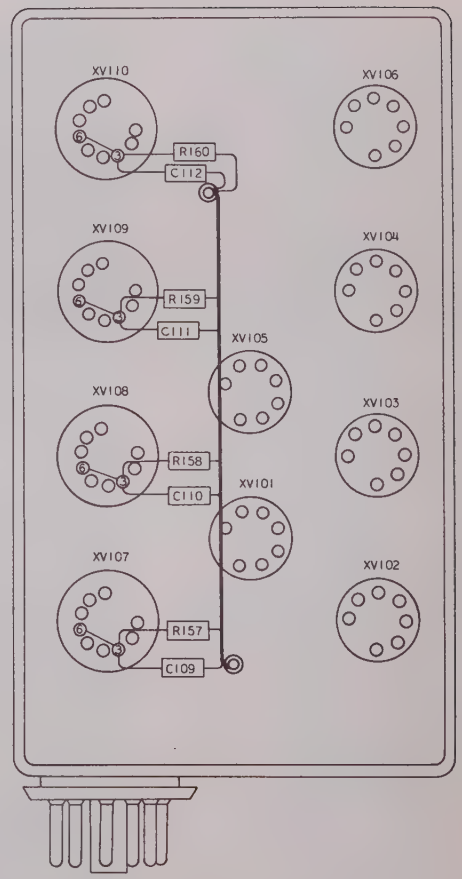
FIGURE 5. TYPICAL WAVEFORMS WITH IMCS INPUT FREQUENCY. ALL WAVEFORMS BLANKED AT TIME OF EACH INPUT PULSE.



TERMINAL BOARD. INNER SIDE



TERMINAL BOARD. SIDE EXPOSED
WHEN COVER IS REMOVED



TUBE SOCKETS VIEWED
FROM INNER SIDE.

FIGURE 7. PARTS LOCATION

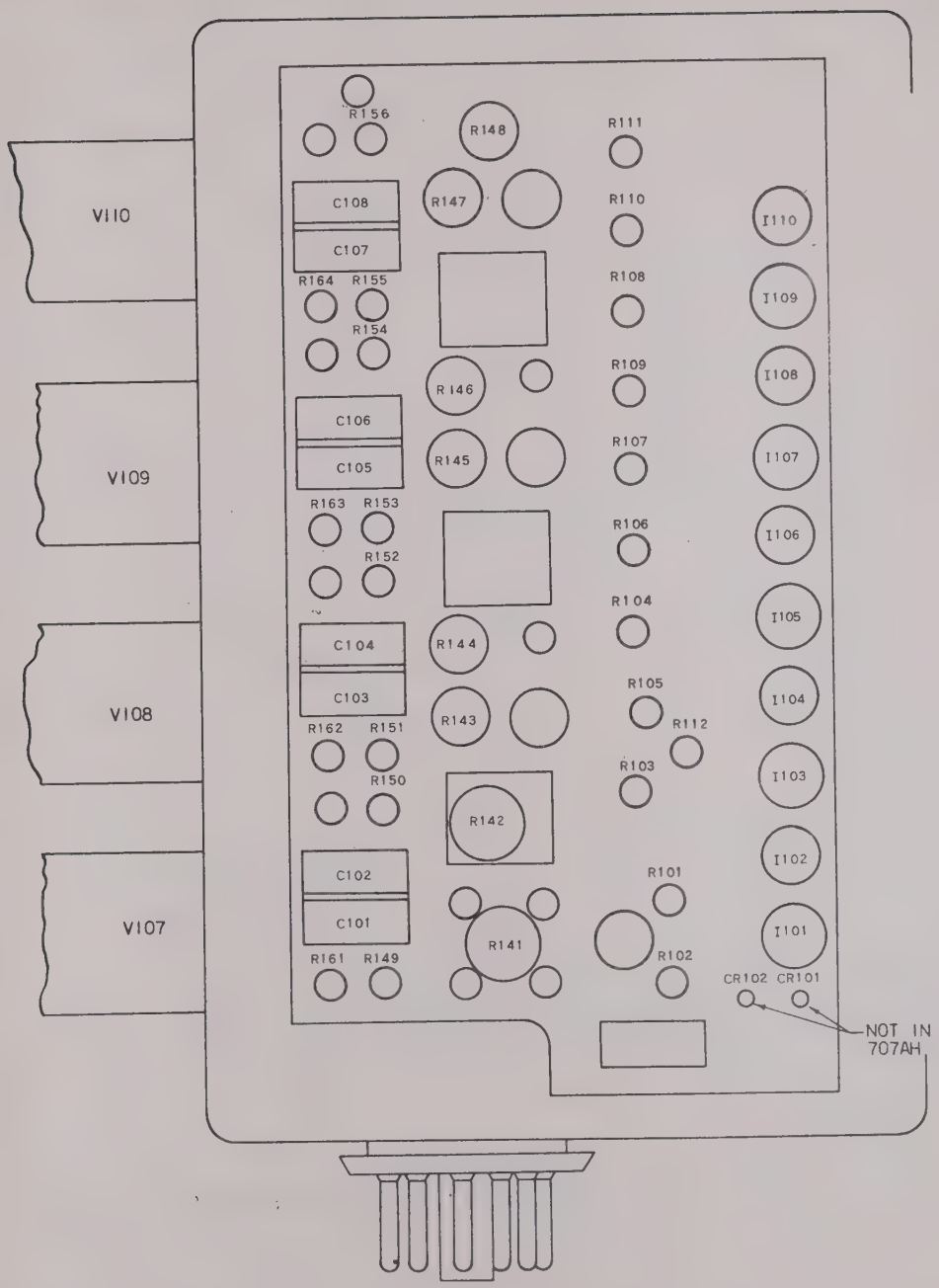
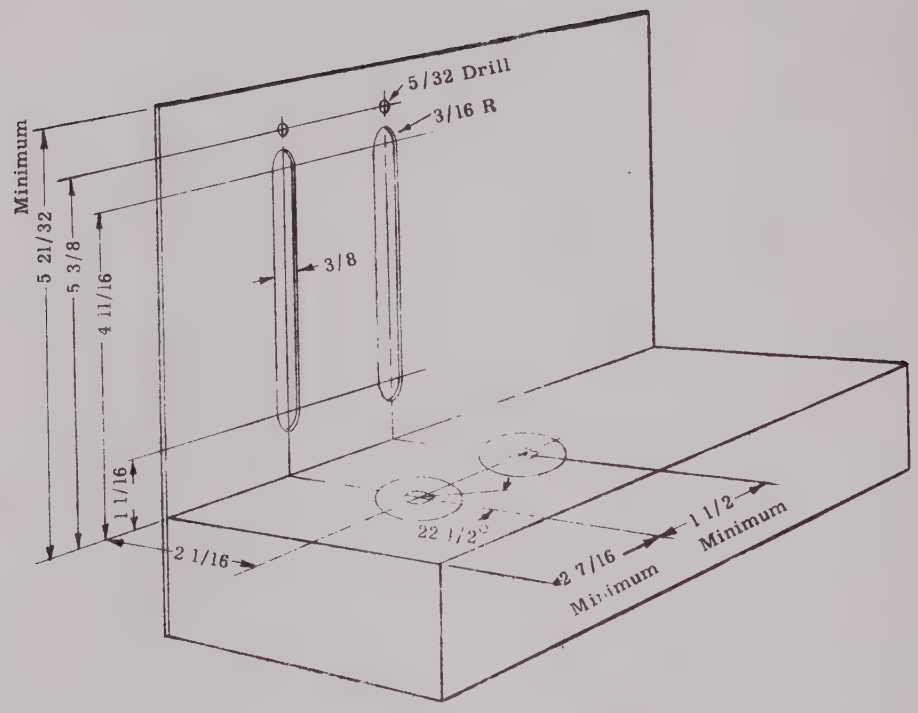


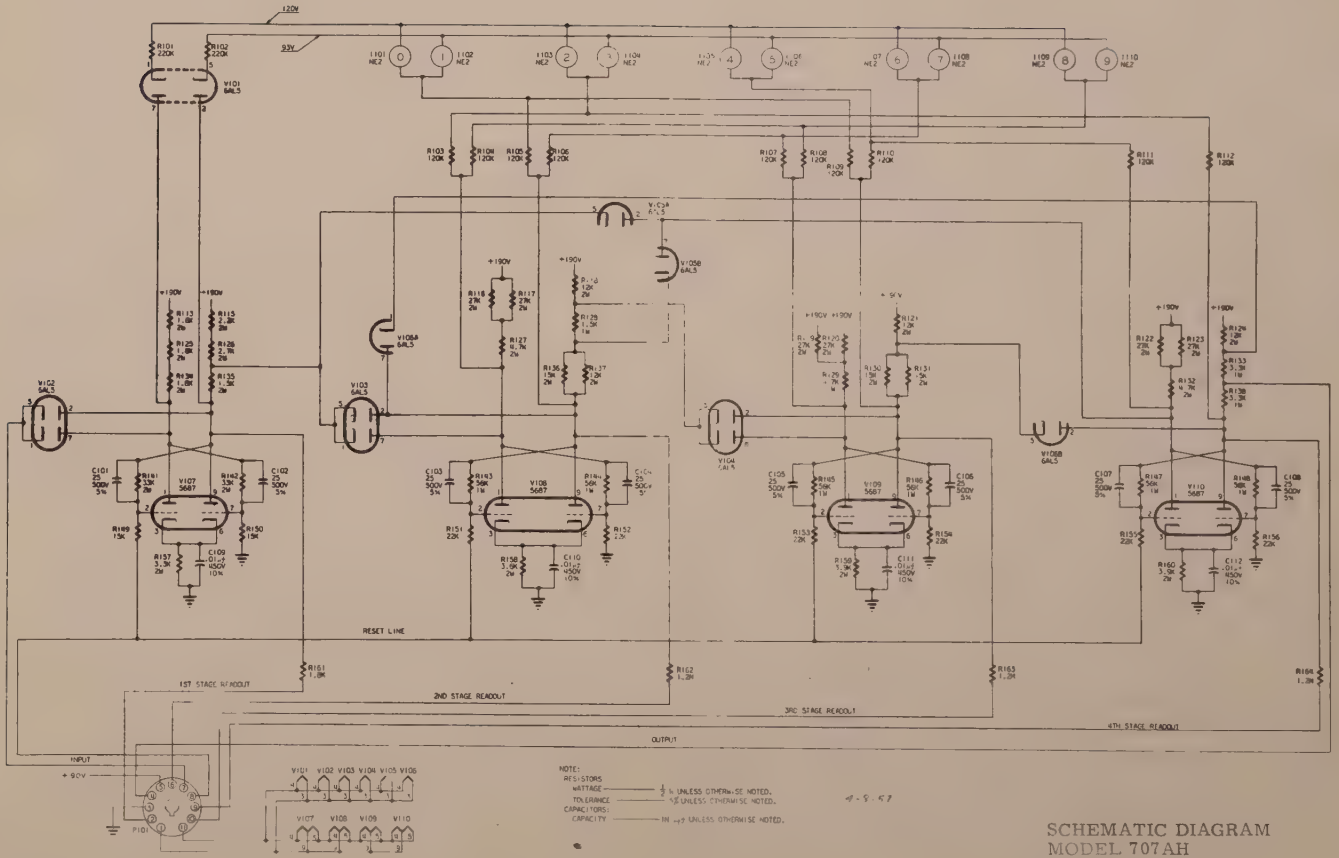
FIGURE 6. PARTS LOCATION



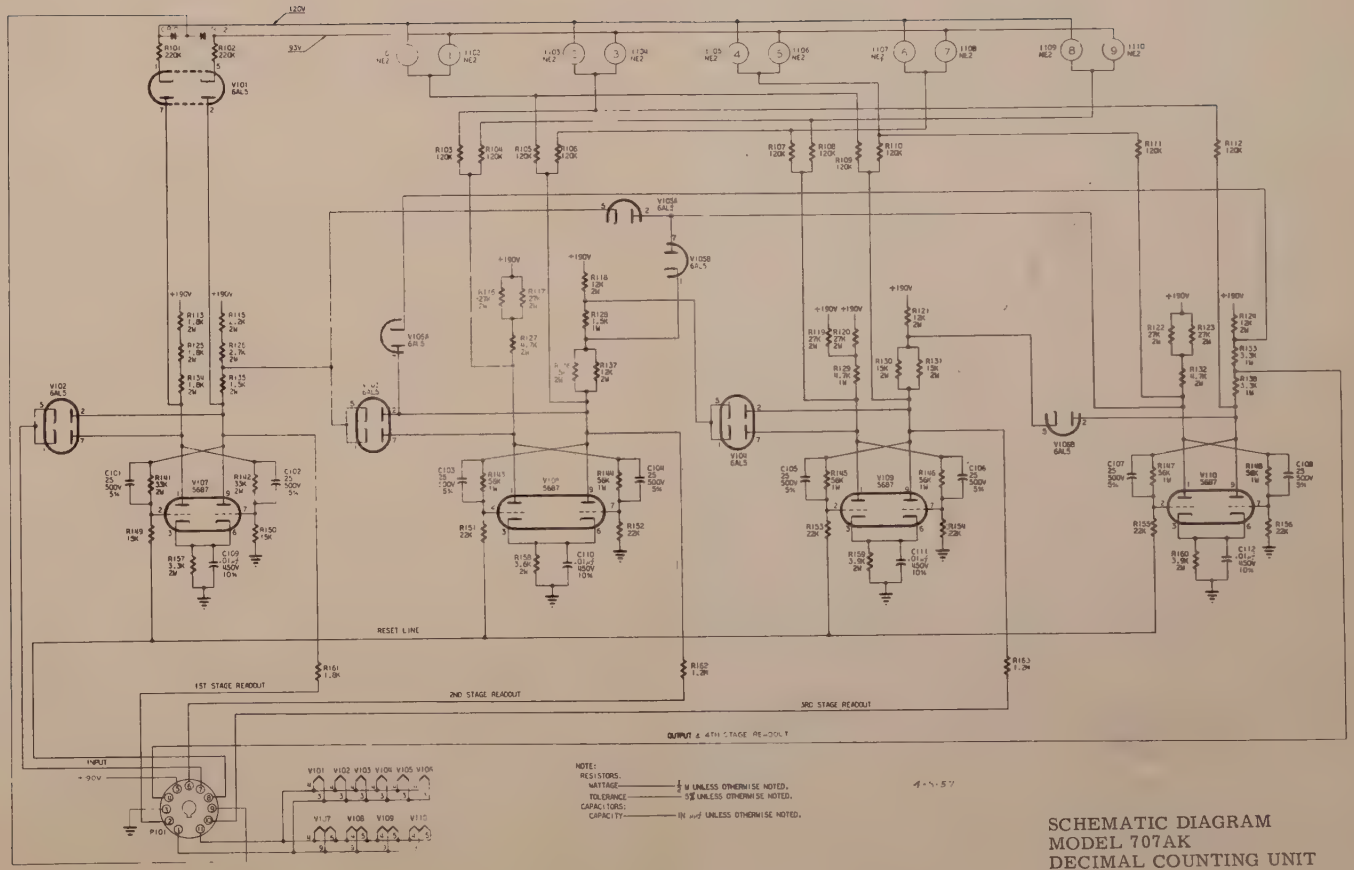
NOTE: Dimensions are based on the use of Amphenol "MIP" sockets mounted above the chassis.

The drawing shows chassis dimensions for mounting a Model 707A next to a Model 705A, which is customarily the next DCU in a cascade arrangement. All modifications of the Model 707A (707AH, 707AF, etc.) have precisely the same dimensions as the standard 707A. All modifications of the Model 705A have the same dimensions as that unit.

Mounting Dimensions, Model 707A and All Modifications Thereof



SCHEMATIC DIAGRAM
MODEL 707AH
DECIMAL COUNTING UNIT
DWG. NO. 707D200



SCHEMATIC DIAGRAM
MODEL 707AK
DECIMAL COUNTING UNIT
DWG. NO. 707D500

J-T-GILLANDERS

Beckman service memo

SM 60-4
March, 1960

1 Mc Crystal and Oven Assembly

Upon replacing a crystal in 7000 series instruments, take a look at the oscillator wave shape and select a new value of RXXX, if necessary. In most cases, absence of the oscillator signal is caused by too low a value of RXXX. Select a resistor large enough to cause definite distortion of the positive peak of the wave form. Be sure to recalibrate the oscillator against WWV or a similar standard.

The crystal oven in 7000 series instruments is always on as long as the instrument is plugged into the line, even though the power switch is turned off. This feature permits accurate measurements soon after the power is turned on because the crystal always remains at a constant temperature. If an instrument is plugged-in for a year, the oven accumulates 8766 hours and the cycling contacts operate all the time in order to keep the temperature constant at 75° centigrade.

The three most common troubles encountered by Beckman/Berkeley Service personnel are:

1) Burnt out ovens
2) Heater shorted to ground
3) Noisy contacts

1) Burnt out ovens. Upon removal from the fibreglass-lined can, the epoxy resin coating of the oven shows a dark burnt color and probably smells burnt. There is no repair possible, even by the manufacturer. Replace the oven and the contained crystal if it has been damaged by excess heat. If the tiny lead-sealed evacuation hole in the crystal jacket has been melted open, be sure to replace the crystal.

2) Heater shorted to ground. A normal oven, when unplugged from the instrument, will read about 400 ohms across the heater, pin 1 to 6. There should be no connection from the heater to ground, pin 5. If there is, discard the oven at once. Measured with an ohmmeter, the resistance from ground to the heater should be almost infinite.

3) Noisy contacts. Noisy oven cycling contacts may cause errors in the E/UT and TEST functions. For example, with the TIME-SECONDS switch set at 1 and the Function switch set at TEST, the count may be short of 1,000,000 by 15 to 300. The erroneous result may occur only once in 5, 10 or more samples.

Watch the oven light indicator on the front-panel and see if it lights during an erroneous TEST measurement. Notice if it appears to be cycling normally. Buzzing contacts may not light the indicator lamp at all.

J-T-GILLANDERS

Note

The reason for erratic short counts is sporadic division by 9 in the first divider, caused by the high noise peaks resulting from noisy contacts. So be sure the first divider is exactly centered within its divide-by-10 range.

Mild cases of noisy contacts may be cured by installation of two .01 mf disc capacitors on the oven socket; pin 1 to ground and pin 6 to ground. If these capacitors do not solve the problem a new oven must be installed. When installing a new oven, the capacitors, if not present, should be added to forestall future noise problems. At any rate, removal of the suspect oven and replacement by a new one is the surest way to eliminate the source of the count error.

How to return a crystal for service or replacement:

(a) Package the crystal well. A little foresight here may prevent further damage to the unit.

(b) Be sure to identify the parent instrument of ovens returned to us for in-warranty replacement.

(c) If the oven was purchased by separate sale, give us the sales order number.

(d) Tag the oven, explaining the nature of the trouble, if known.

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